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Water Quality

RESOURCE QUALITY SECTION
WATER MANAGEMENT BRANCH
MINISTRY OF ENVIRONMENT AND PARKS

AMBIENT WATER QUALITY OBJECTIVES FOR BOUNDARY BAY AND ITS TRIBUTARIES FRASER-DELTA AREA

OVERVIEW REPORT

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SUMMARY

This report assesses the water quality of Boundary Bay and its major tributaries: the Little Campbell River, the Serpentine River and the Nicomekl River. Provisional water quality objectives are set to protect aquatic life and recreation in Boundary Bay, and aquatic life, wildlife, irrigation and livestock watering in the tributaries.

Boundary bay sustains a crab and herring fishery and the tributaries provide important habitat for steelhead and cutthroat trout and coho and chum salmon.

Most of the water contamination comes from diffuse agricultural sources. It has raised levels of nutrients, biochemical oxygen demand and fecal coliforms in the major tributary streams. As a result, oxygen deficiencies have occurred in the streams causing problems for fish, and the water must be completely treated before domestic use. The effect in Boundary Bay is that fecal coliform levels are too high for shellfish harvesting, although the levels are suitable for swimming.

Provisional water quality objectives have been set for nutrients, dissolved oxygen and fecal coliforms. Attainment of

these objectives will protect aquatic life and will be one factor enabling shellfish harvesting to return to Boundary Bay. A strategy to identify and to control agricultural sources of contamination will need to be developed to achieve these objectives consistently.

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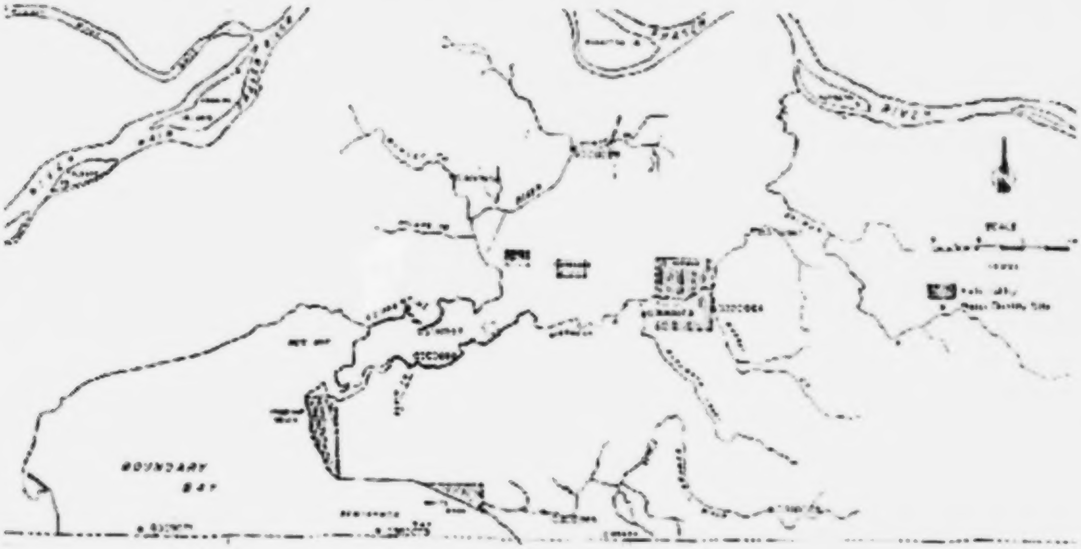
Figure 1. Fraser River Sub-Basin: Boundary Bay and its Tributaries



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PREFACE

Purpose of Water Quality Objectives

Water quality objectives are prepared for specific bodies of fresh, estuarine and coastal marine surface waters of British Columbia as part of the Ministry of Environment, Lands and Parks' mandate to manage water quality. Objectives are prepared only for those waterbodies and water quality characteristics that may be affected by human activity now or in the near future.

How Objectives Are Determined

Water quality objectives are based the BC approved and working criteria as well as national water quality guidelines. Water quality criteria and guidelines are safe limits of the physical, chemical, or biological characteristics of water, biota (plant and animal life) or sediment which protect water use. Objectives are established in British Columbia for waterbodies on a site-specific basis. They are derived from the criteria by considering local water quality, water uses, water movement, waste discharges, and socio-economic factors.

Water quality objectives are set to protect the most sensitive designated water use at a specific location. A designated water use is one that is protected in a given location and is one of the following:

- raw drinking water, public water supply, and food processing
- aquatic life and wildlife
- agriculture (livestock watering and irrigation)
- recreation and aesthetics
- industrial water supplies.

Each objective for a location may be based on the protection of a different water use, depending on the uses that are most sensitive to the physical, chemical or biological characteristics affecting that waterbody.

How Objectives Are Used

Water quality objectives routinely provide policy direction for resource managers for the protection of water uses in specific waterbodies. Objectives guide the evaluation of water quality, the issuing of permits, licences and orders, and the management of fisheries and the province's land base. They also provide a reference against which the state of water quality in a particular waterbody can be checked, and help to determine whether basin-wide water quality studies should be initiated.

Water quality objectives are also a standard for assessing the Ministry's performance in protecting water uses. While water quality objectives have no legal standing and are not directly enforced, these objectives become legally enforceable when included as a requirement of a permit, licence, order, or regulation, such as the Forest Practices Code Act, Water Act regulations or Waste Management Act regulations.

Objectives and Monitoring

Water quality objectives are established to protect all uses which may take place in a waterbody. Monitoring (sometimes called sampling) is undertaken to determine if all the designated water uses are being protected. The monitoring usually takes place at a critical time when a water quality specialist has determined that the water quality objectives may not be met. It is assumed that if all designated water uses are protected at the critical time, then they also will be protected at other times when the threat is less.

The monitoring usually takes place during a five week period, which allows the specialists to measure the worst, as well as the average condition in the water.

For some waterbodies, the monitoring period and frequency may vary, depending upon the nature of the problem, severity of threats to designated water uses, and the way the objectives are expressed (*i.e.*, mean value, maximum value).

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INTRODUCTION

This report examines the water quality in the Little Campbell River, Serpentine River, the Nicomekl River and their tributaries and Boundary Bay (Figure attached). For convenience, Boundary Bay is taken here to include Mud Bay and the Canadian portion of Semiahmoo Bay. The review covers water quality and effluent quality data for the period 1972 to 1986. The main purpose of the review was to develop water quality objectives in areas where designated water uses are threatened, either now or in the future, so that these objectives could be used by the Greater Vancouver Regional District in the preparation of their liquid waste management plan. The conclusions in this report are based on a more detailed technical appendix.

The Little Campbell River is approximately 30 km in length and has a drainage area of about 65 km^2. The Nicomekl River is approximately 34 km in length and together with Anderson and Murray Creeks, its major two tributaries, has a drainage area of 149 km^2. The 116 km^2 Serpentine River drainage basin contains the 35 km Serpentine River as well as Latimer, Mahood (Bear) and Hyland Creeks, it main tributaries.

Boundary Bay is located on the south side of the Fraser-Delta area approximately 19 km south from the City of Vancouver. It is 15 km long and 4 km wide and covers an area of about 6085 ha. The Bay is rectangular in shape and faces southeast onto the Straight of Georgia.

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HYDROLOGY AND OCEANOGRAPHY

Sufficient flow data were not collected on the Little Campbell River to calculate 7-day average low flows; however the mean daily flow between 1961 and 1964 was 0.94 m^3/s. On the Serpentine River upstream from Mahood Creek, the estimated two-year, 7-day average low flow was 0.057 m^3/s, based upon data from only two partial years. On Mahood (Bear) Creek, the two-year, 7-day low flow was 0.073 m^3/s, while the ten-year, 7-day low flow was 0.0175 m^3/s. Two- and ten-year, 7-day average low flows in the Nicomekl River drainage were 0.24 m^3/s and 0.13 m^3/s on the Nicomekl River; 0.149 m^3/s and 0.13 m^3/s on Anderson Creek and 0.006 m^3/s and 0.001 m^3/s on Murray Creek, respectively.

Water movement within Mud and Boundary Bays is tidally influenced with respect to flushing and velocity. Seasonally, flushing occurs on a daily basis in October and from January to June and twice per day for the remainder of the year. Ebb tides are more concentrated on the eastern side. Water entering Boundary Bay comes from Puget Sound, Drayton Harbour and the Serpentine River, as well as the Strait of Georgia.

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WATER USES

The Little Campbell, Serpentine and Nicomekl Rivers and their tributaries provide important spawning and rearing habitat for steelhead and cutthroat trout and coho and chum salmon. The Little Campbell River system ranks fifth or sixth in steelhead angling importance in the Lower Mainland Region. Boundary Bay sustains crab and herring fisheries, is used as a migratory corridor by salmonids to reach spawning areas and in the past has sustained an oyster fishery which had to be closed because of unacceptable bacteriological quality.

Primary-contact (swimming) recreation takes place in the Little Campbell River at one location and at several beaches in Boundary Bay.

Water from the Little Campbell, Serpentine and Nicomekl Rivers and their tributaries is used for irrigation, livestock watering and drinking. For irrigation on a yearly basis, 686 dam^3 is licenced from the Little Campbell River, 2085 dam^3 is licenced from the Serpentine River and 2272 dam^3 is licenced from the Nicomekl River. For drinking water supplies 12.8 m^3/d is licenced from the Little Campbell River, 4.6 m^3/d is licenced from the Serpentine River and 11.4 m^3/d from the Nicomekl River. These waters are not approved by the Ministry of Health as drinking water sources for public water supplies. An alternative source of water exists through the Greater Vancouver Water District should this area approach urban population densities. Livestock watering is a licenced use on the Little Campbell (242 $dam^3/year$), the Nicomekl (9.8 $dam^3/year$) and the Serpentine (0.4 $dam^3/year$) Rivers.

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WASTE DISCHARGES

Most of the operations discharging effluents within the Little Campbell drainage basin use soil disposal. This, combined with the small quantities of wastewater involved, makes these discharges of little concern to the water quality within the drainage basin. Exceptions are two feedlot operations which intermittently discharge to tributaries within the drainage basin. An impact on the water quality of one tributary adjacent to one feedlot operation has caused nuisance algal growths in the tributary creek.

No permitted effluent is discharged directly to the Serpentine River; however, untreated cooling water, stormwater and effluent from an iron foundry are discharged to Mahood (Bear) Creek, its major tributary. Treated stormwater runoff from a concrete ready-mix operation is discharged to a second tributary, Hyland Creek. The remaining operations discharge effluent to soil disposal systems. No impact on water quality has been observed; however, it appears from loading calculations that iompacts are possible from PCBs and oil and grease.

In 1984 a fish kill occurred in Highland Creek as the result of a chlorophenol spill. Chlorophenols are not discharged normally into the Serpentine River or its tributaries. The 1984 spill was an isolated incident and there was no lasting impact on the Serpentine River system.

Discharges of most effluents within the Nicomekl drainage basin have not been observed to impact the river. These discharges include several soil disposal systems. Leachate from one landfill operation has severely impacted a tributary used for spawning and caused fungal growths in the Nicomekl River itself.

Sewage pump stations in White Rock were connected to the Greater Vancouver Sewage and Drainage District (GVS and DD) in 1977. Pump stations near Cresent Beach can overflow during power or pump failures. The Semiahmoo Indian Band reserve was unsewered in 1977 with possible septic tank seepage occurring at three residences. This area remains unsewered. There are no permits to discharge wastes into Boundary Bay.

Diffuse agricultural sources can influence ammonia, phosphorus, BOD_5 and fecal coliform concentrations in the Little Campbell, Serpentine and Nicomekl Rivers and their tributaries. This is probably the most notable influence on water quality, other than urban stormwater runoff, within these water sheds. Other factors related to water quality are floodgates to prevent outward flow of the rivers at high tides.

There are no houseboat communities in Mud Bay or Boundary Bay. Sewage from Cresent Beach Marina in Surrey is sent via a sanitary sewer to the Annacis Island Sewage Treatment Facility. Sewage from the marina at the mouth of the Nicomekl River also goes to this facility.

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WATER QUALITY

Water quality for the period of record throughout the Little Campbell River was characteriuzed by low metal and ammonia-nitrogen values and moderate to low buffering to acidic discharges. The water is usually moderately soft. Nitrate-nitrogen and phosphorus concentrations were elevated during periods of low flow and high temperature. These can lead to excessive algal growths. Dissolved oxygen values were low and percent saturation varied widely in certain reaches, providing a low level of protection to mature salmonids and still less protection for egg-to-juvenile stages. Bacteriological quality, in terms of fecal coliform concentrations, was generally poor throughout the system.

The pH in the Serpentine river can vary by as much as 3.0 pH units from minimum to maximum. Alkalinity values can be from moderate to low and the water would be classed as soft. Some high metal values for total aluminum, copper, lead, iron, manganese and zinc have been measured but are thought to be either naturally occurring or possibly due to stormwater. If phosphorus is the limiting factor values were high enough to cause algal blooms. Ammonia and nitrite toxicity are thought not to be a concern. Large variations occurred in dissolved oxygen and percent saturation values, likely due to algal respiration. These variations are sufficient to put aquatic life under severe stress with low dissolved oxygen concentrations providing a low level of protection to mature salmonids. Oxygen-consuming materials also exert a demand for oxygen. Fecal coliform values were high. Dissolved solids reflected the influence of saltwater intrusion near the mouth but were not so high in the upper reaches as to restrict and water uses.

The Nicomekl River basin has naturally high pH and is well buffered to acidic inputs. Some higher metal values were recorded but these were likely naturally occurring. High lead values may originate from stormwater discharges. Ammonia and nitrite values met criteria to protect aquatic life. High levels of phosphorus and oxygen-consuming materials are believed to be responsible for low dissolved oxygen levels and wide fluctuations in percent saturation values. This situation occurs because phosphorus promotes algal growth which, in turn, due to photosynthesis, respiration and decay, can cause either a depletion or excess in dissolved oxygen concentrations. These effects were not as pronounced in two tributary creeks, Murray and Anderson, or the headwaters of the Nicomekl River, as they were in the majority of the Nicomekl River. Fecal coliform levels were hiogh. High dissolved solids near the mouth of the Nicomekl River reflect saltwater intrusion.

Water quality in Boundary Bay was generally consistent for the period of record. Data for pH, nutrients and most metals were within the range to protect marine aquatic life. Values for copper, lead, mercury and zinc occasionally exceeded working criteria; these may be either natural background levels in Boundary Bay or may originate from surface runoff from the City of White Rock or sewage discharges and surface runoff from Blaine or Drayton Harbour. Dissolved oxygen levels were sufficient to support marine life. Fecal coliforms were too high to permit the harvesting of shellfish but were within current standards to permit use of the Bay for swimming.

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PROVISIONAL WATER QUALITY OBJECTIVES

A summary of designated water uses and proposed provisional water quality objectives in given in Table 1. Provisional water quality objectives are proposed for the Little Campbell River, the Serpentine River, the Nicomekle River and their tributaries, and Boundary Bay. The objectives are based on approved Ministry criteria as well as preliminary working criteria foer water quality and on available data on ambient water quality, waste discharges, water uses and river flows. The objectives will renmain provisional until receiving water monitoring programs provide adequate data, and the Ministry has established approved water quality criteria for all the characteristics of concern.

Water quality objectives have no legal standing and would not be directly enforced. The objectives ares policy guidelines for resource managers to protect water uses in the specified water bodies.They will guide the evaluation of water quality, the issuing of permits, licences and orders and the management of the fisheries and of the Province's land base.They also provide a reference against which the state of water quality in a particular water body can be checked, and serve to make decisions on whether to initiate basin-wide water quality studies.

Depending on the circumstances, water quality objectives may already be met in a water body, or may describe water quality conditions which can be met in the future. To limit the scope of the work, objectives are only being prepared for waterbodies and for water quality characteristics which may be affected by man's activity, now and in the foreseeable future.

Designated water uses, including protection of aquatic life and wildlife, drinking water (complete treatment), irrigation and livestock watering are proposed for the Little Campbell, Serpentine and Nicomekl River basins. The drinking water use is not designated fo tributaries of the Serpentine River. Primary-contact recreation is proposed in addition for the Little Cambell River as well as for Boundary Bay where the protection of aquatic life and wildlife is also a designated use.

Ammonia can be toxic to aquatic life. Objectives therefore are proposed for the Little Campbell, Serpentine and

Nicomekl River drainage basins since ammonia nitrogen can enter all three systems from agricultural operations (Table 2 and Table 3). The proposed objectives were met. Corresponding objectives for nitrite are proposed, since the incomplete oxidation of ammonia can produce toxic concentrations of nitrite (Table 4).

The proportion of ammonia that is toxic in aqueous solution is a function of the corresponding specific conductivity, temperature and pH. Therefore a pH objective is also proposed for these water bodies. A lower maximum pH is proposed for the Little Campbell River, as well as for the Serpentine and Nicomekl Rivers and Murray and Anderson Creeks, since the background pH is lower in these streams, and the amount of ammonia toxicity is greatly reduced at lower pH values.

Fecal coliform objectives are proposed to protect bathing beaches in Boundary Bay and the Little Campbell River from April through October and to maintain existing conditions in Mahood, Hyland and Latimer Creeks. These proposed objectives were usually met. A less stringent objective is proposed for the Serpentine and Nicomekl Rivers and Anderson and Murray Creeks to maintain existing conditions and to protect irrigation water supplies. A more stringent long-term objective is proposed for all the freshwater bodies to upgrade their quality to meet higher irrigation standards for crops eaten raw. Such improvements would also help to achieve the long-term objective for fecal coliforms in Boundary Bay which, if met, would permit shellfish harvesting to take place once again. This assumes the habitat is still suitable for shellfish growth. Consideration could be given to controlled commercial harvesting which would be subject to controlled purification requirements and/or eventual "conditional openings" of the area at certain times of the year as bacteriological quality improves.

Objectives have been proposed in all the water bodies for suspended solids to prevent possible physical damage to aquatic life. As well an objective for substrate sedimentation is also proposed to protect spawning beds. Objectives for turbidity are meant to address the effect of light attenuation on aquatic life.

Peripyton chlorophyll-*a* objecxtives have been proposed to control algal growth so that excessive growth will not occur which would impair use. Although measurements have not been made, it is suspected that the proposed objective will not be met since large fluctuations in dissolved oxygen levels would appear to indicate problems with algal growths. Therefore, the objective for chlorophyll-a may have to be a long-term objective which will require action to eliminate nutrient sources.

Two different objectives are proposed for dissolved oxygen in the freshwater tributaries to Boundary Bay to protect spawning and rearing habitats for trout and salmon. Each objective is dependent upon the life stage (*e.g.*, egg, alevin or fry) of the affected fish. In addition, in order to upgrade dissolved oxygen levels, a long-term minimum value is proposed which is higher than can be presently achieved; however, a second long-term objective is proposed to improve levels in the Bay.

An objective for total lead is proposed for the Nicomekl River, due to the concern for inputs of stormwater from Langley.

Objectives for PCBs are proposed in the water column, bottom surface sediments and fish in Mahood Creek and the Serpentine River since PCBs can potentially be discharged from a BC Hydro Facility. An objective for PCBs is proposed for sediments in Boundary Bay since these contaminants may settle in the Bay.

Should a development be proposed in the future for any of these watersheds where provisional objectives do not exist for characteristics of concern, the designated water uses should be protected while objectives are developed for these characterictics.

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MONITORING RECOMMENDATIONS

Several monitoring programs have been proposed (Table 5), some dealing with verifying achievement of the proposed water quality objectives and others to aid in the development of further objectives. Appropriate monitoring of waste discharges should be conducted at the same time as receiving water monitoring. The recommended monitoring is based upoin technical considerations, and actual programs will depend on budget allocations and project priorities.

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TABLES

Table 1 Provisional Water Quality Objectives for the Little Campbell River, Nicomekl River, Serpentine River, their tributaries and Boundary Bay

Water Bodies	Little Campbell River (and tributaries)	Mahood, Hyland and Latimer Creeks	Serpentine River	Nicomekl River	Anderson and Murray Creeks	Boundary Bay
Designated Water Uses	aquatic life, wildlife, irrigation, livestock watering, primary-contact recreation	aquatic life, wildlife, irrigation, livestock watering	aquatic life, wildlife, irrigation, livestock watering	aquatic life, wildlife, irrigation, livestock watering	aquatic life, wildlife, irrigation, livestock watering	aquatic life, wildlife, primary-contact recreation
fecal coliforms	less than or equal to 200 MPN/100 mL as a geometric mean from April to October less than or equal to 400 MPN/100 mL as a 90th percentile from April to October	less than or equal to 1000 MPN/100 mL as a geometric mean from April to October less than or equal to 4000 MPN/100 mL as a maximum from April to October				less than or equal to 200 MPN/100 mL as a geometric mean from April to October less than or equal to 400 MPN/100 mL as a 90th percentile from April to October
						less than or equal to 14 MPN/100 mL as a median year round (long-term

<table>
<tr><td>fecal coliforms</td><td>not applicable</td><td colspan="4">less than or equal to 200 MPN/100 mL as a geometric mean year round (long-term objective)</td><td>objective) less than or equal to 43 MPN/100 mL as a 90th percentile year round (long-term objective)</td></tr>
<tr><td>Suspended solids</td><td colspan="6">10 mg/L maximum increase when upstream values are less than or equal to 100 mg/L
10% maximum increase when upstream values exceed 100 mg/L</td></tr>
<tr><td>Substrate sedimentation</td><td colspan="6">no significant increase (95% confidence level) by weight in particulate matter for particles up to 3 mm in diameter</td></tr>
<tr><td>Turbidity</td><td colspan="6">5 NTU maximum increase when upstream values are less than or equal to 50 NTU
10% maximum increase when upstream values exceed 50 NTU</td></tr>
<tr><td>Ammonia-nitrogen, total</td><td colspan="5">Maximum Concentration of Total Ammonia Nitrogen for Protection of Aquatic Life.
Average 30-day Concentration of Total Ammonia Nitrogen for Protection of Aquatic Life.</td><td>not applicable</td></tr>
<tr><td>Nitrite-nitrogen</td><td colspan="5">Maximum and 30-day average Allowable Nitrite (N) Concentration</td><td>not applicable</td></tr>
<tr><td>periphyton chlorophyll-a</td><td>50 mg/m^2 maximum average</td><td colspan="2">100 mg/m^2 maximum average (long-term objective)</td><td colspan="2">100 mg/m^2 maximum average</td><td>not applicable</td></tr>
<tr><td rowspan="3">Oxygen, dissolved</td><td>6.0 mg/L minimum June to October</td><td>8.0 mg/L minimum</td><td colspan="2">6.0 mg/L minimum June to October</td><td>8.0 mg/L minimum</td><td rowspan="3">6.5 mg/L minimum 9.0 mg/L minimum as a long-term objective</td></tr>
<tr><td>8.0 mg/L minimum June to October long-term objective</td><td>not applicable</td><td colspan="2">8.0 mg/L minimum June to October long-term objective</td><td>not applicable</td></tr>
<tr><td colspan="5">11.0 mg/L minimum when salmonid eggs, larvae or alevin are present</td></tr>
<tr><td>pH</td><td>6.5 to 8.5</td><td colspan="4">6.5 to 8.5 or
0.2 maximum increase when u/s is less than 8.5</td><td>not applicable</td></tr>
<tr><td></td><td colspan="3"></td><td>0.005 mg/L</td><td colspan="2"></td></tr>
</table>

Lead, total	**not applicable**		**average 0.010 mg/L maximum**	**not applicable**	
PCBs	**not applicable**	**0.001 micrograms/L maximum in water 0.03 micrograms/g dry weight maximum in bottom surface sediments 0.1 micrograms/g wet weight in whole small fish subject to predation 0.5 micrograms/g wet weight in muscle of larger fish eaten by man**	**not applicable**		**0.03 micrograms/g dry weight maximum in bottom surface sediments**

Note: The objectives apply to discrete samples from all parts of the water body except from initial dilution zones of effluents. These excluded dilution zones are defined as extending up to 100 m downstream from the discharge point and no more than 50 percent across the width of the stream, from the surface to the bottom. These excluded dilution zones in the Bay are defined as extending up to 100 m horizontally in all directions and not to exceed more than 25 percent of the width of the waterbody.

1. The fecal coliform geometric mean, median and 90th percentile are calculated from at least 5 samples taken weekly in a period of 30 days. The recreation objective (200-400/100 mL) applies during the recreation season and the irrigation objectives (1000-4000/100 mL) applies during the irrigation season.

2. The increase (in NTU, mg/L or %) for turbidity and suspended solids, is over levels measured at a site u/s from a discharge or series of discharges and as close to them as possible, and applies to d/s levels. In Boundary Bay control samples should be obtained from areas of similar physical characteristics to those areas where measurements near a discharge are to be made.

3. The periphyton chlorophyl-a average is calculated from at least 5 randomly located samples taken from natural substrates at each site on any one sampling date.

4. pH measurements may be made in-situ but must be confirmed in the laboratory if the objective is exceeded.

5. The total lead is calculated from at least 5 weekly samples taken in a period of 30 days.

6. PCB objectives do not apply to Hyland or Latimer Creeks. The term PCBs applies to the sum of Aroclor 1242, 1254 and 1260 which may be present in water, sediment or fish. The maximum value should not be exceeded in bottom surface sediments taken in any part of the sub-basin, except in the initial dilution zones of effluents. The average of at least three replicate sediment samples taken from the same site should be used to check the objectives. Also, the objective applies to fish of any species caught in any part of the creeks or river, including the initial dilution zones of effluents.

Table 5 Recommended Effluent and Water Quality Monitoring for Boundary Bay and its Tributaries

Sites	**Frequency and Timing**	**Characteristics to be Measured**

Little Campbell River (sites 0300065 and 0300066)	five samples in a 30-day period June to September and November to January	dissolved oxygen, pH, temperature, specific conductivity, ammonia-N, nitrite-N, nitrate-N, dissolved orthophosphorus, total ophosphorus, fecal coliforms, turbidity, suspended sediments, substrate sedimentation, dissolved solids, periphyton chlorophyll-*a*, dissolved and total copper, iron, manganese and lead.
Nicomekl River (sites 0300060 and 0300062)		
Anderson Creek (site 0300063)		
Murray Creek (site 0300064)		
Latimer and Hyland Creeks near the mouth		
Serpentine River (sites 0300057 and 0300059)		dissolved oxygen, pH, temperature, specific conductivity, ammonia-N, nitrite-N, nitrate-N, dissolved orthophosphorus, total ophosphorus, fecal coliforms, turbidity, suspended sediments, substrate sedimentation, dissolved solids, periphyton chlorophyll-*a*, dissolved and total copper, iron, manganese and lead, PCBs.
Mahood Creek (site 0300056)		
Little Campbell, Nicomekl and Serpentine Rivers (sites to be determined)	once per year timing to be determined	determine impact of land use on water quality in the river basins characteristics to be determined
Mahood Creek (sites to be determined)	once, timing to be determined	determine if the discharges from two foundaries are significantly affecting water quality
Boundary Bay (sites 0300070 and 0300071d)	5 samples in a 30-day period	dissolved oxygen, fecal coliforms and PCBs in sediments

Note: Sampling may need to be increased to check objectives, depending on circumstances.

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WATER QUALITY

Water Quality Criteria for Nitrogen (Nitrate, Nitrite, and Ammonia)

Overview Report

Prepared pursuant to Section 2(e) of the
Environment Management Act, 1981

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Original signed by Ben Marr
Deputy Minister
November 12, 1986

Updated: August 7, 2001

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Preface

Recommended Guidelines

Application of the Guidelines

NOTE: The marine ammonia criteria found in this document have been replaced by newer

values found in the document *Ambient Water Quality Guidelines for Ammonia to Protect Marine Aquatic Life.*

Tables

Table 1. Summary of Water Quality Criteria for Nitrogen

Water Use	Nitrate mg/L as Nitrogen	Nitrite mg/L as Nitrogen	Ammonia (total) mg/L as Nitrogen
Drinking Water	10 mg/L (maximum)	1 mg/L (maximum)	None proposed
Fresh Water Aquatic Life - maximum	200 mg/L (maximum)	0.06 mg/L (maximum)	see Tables 3 and 4
Fresh Water Aquatic Life - average	less than or equal to 40 mg/L (average)	2 mg/L (average) when the chloride is less than or equal to 0.02 mg/L - also see Table 2	see Tables 3 and 4
Marine Aquatic Life - maximum	None proposed	None proposed	2.5 mg/L (maximum)
Marine Aquatic Life - average	None proposed	None proposed	less than or equal to 1.0 mg/L (average)
Livestock Watering	100 mg/L (maximum)	10 mg/L (maximum)	None proposed
Wildlife	100 mg/L (maximum)	10 mg/L (maximum)	None proposed
Recreation and Aesthetics	10 mg/L (maximum)	1 mg/L (maximum)	None proposed

1. The average value is calculated from at least 5 weekly samples taken in a period of 30 days.

2. Where nitrate and nitrite are present, the total nitrate-nitrite nitrogen should not exceed these values.

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Table 2. Criteria for Nitrite for Protection of Freshwater Aquatic Life

Chloride in mg/L	Nitrite (maximum)	Nitrite (average)

	mg/L as Nitrogen	mg/L as Nitrogen
less than 2 mg/L	0.06 mg/L	0.02 mg/L
2 to 4 mg/L	0.12 mg/L	0.04 mg/L
4 to 6 mg/L	0.18 mg/L	0.06 mg/L
6 to 8 mg/L	0.24 mg/L	0.08 mg/L
8 to 10 mg/L	0.30 mg/L	0.10 mg/L
greater than 10 mg/L	0.60 mg/L	0.20 mg/L

The 30-day average chloride concentration should be used to determine the appropriate 30-day average nitrite criterion.

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Table 3. Maximum Concentration of Total Ammonia Nitrogen for Protection of Aquatic Life (mg/L of Nitrogen)

Temperature (T) in degrees Celcius

pH	T = 0.0	T = 1.0	T = 2.0	T = 3.0	T = 4.0	T = 5.0	T = 6.0
6.5	27.7	28.3	27.9	27.5	27.2	26.8	26.5
6.6	27.9	27.5	27.2	26.8	26.4	26.1	25.8
6.7	26.9	26.5	26.2	25.9	25.5	25.2	24.9
6.8	25.8	25.5	25.1	24.8	24.5	24.2	23.9
6.9	24.6	24.2	23.9	23.6	23.3	23.0	22.7
7.0	23.2	22.8	22.5	22.2	21.9	21.6	21.4
7.1	21.6	21.3	20.9	20.7	20.4	20.2	19.9
7.2	19.9	19.6	19.3	19.0	18.8	18.6	18.3
7.3	18.1	17.8	17.5	17.3	17.1	16.9	16.7
7.4	16.2	16.0	15.7	15.5	15.3	15.2	15.0
7.5	14.4	14.1	14.0	13.8	13.6	13.4	13.3
7.6	12.6	12.4	12.0	11.9	11.9	11.7	11.6
7.7	10.8	10.7	10.5	10.4	10.3	10.1	10.0
7.8	9.26	9.12	8.98	8.88	8.77	8.67	8.57

7.9	7.82	7.71	7.60	7.51	7.42	7.33	7.25
8.0	6.55	6.46	6.37	6.29	6.22	6.14	6.08
8.1	5.21	5.14	5.07	5.01	4.95	4.90	4.84
8.2	4.15	4.09	4.04	3.99	3.95	3.90	3.86
8.3	3.31	3.27	3.22	3.19	3.15	3.12	3.09
8.4	2.64	2.61	2.57	2.54	2.52	2.49	2.47
8.5	2.11	2.08	2.06	2.03	2.01	1.99	1.98
8.6	1.69	1.67	1.65	1.63	1.61	1.60	1.59
8.7	1.35	1.33	1.32	1.31	1.30	1.29	1.28
8.8	1.08	1.07	1.06	1.05	1.04	1.04	1.03
8.9	0.871	0.863	0.856	0.849	0.844	0.839	0.836
9.0	0.703	0.697	0.692	0.688	0.685	0.682	0.681

Temperature (T) in degrees Celcius

pH	T = 7.0	T = 8.0	T = 9.0	T = 10.0	T = 11.0	T = 12.0	T = 13.0
6.5	26.2	26.0	25.7	25.5	25.2	25.0	24.8
6.6	25.5	25.2	25.0	24.7	24.5	24.3	24.1
6.7	24.6	24.4	24.1	23.9	23.7	23.5	23.3
6.8	23.6	23.4	23.1	22.9	22.7	22.5	22.3
6.9	22.5	22.2	22.0	21.8	21.6	21.4	21.3
7.0	21.1	20.9	20.7	20.5	20.3	20.2	20.0
7.1	19.7	19.5	19.3	19.1	18.9	18.8	18.7
7.2	18.1	17.9	17.8	17.6	17.4	17.3	17.2
7.3	16.5	16.3	16.2	16.0	15.9	15.7	15.6
7.4	14.8	14.7	14.5	14.4	14.2	14.1	14.0
7.5	13.1	13.0	12.9	12.7	12.6	12.5	12.4
7.6	11.5	11.4	11.3	11.2	11.1	11.0	10.9
7.7	9.92	9.83	9.73	9.65	9.57	9.50	9.43
7.8	8.48	8.40	8.32	8.25	8.18	8.12	8.07
7.9	7.17	7.10	7.04	6.98	6.92	6.88	6.83
8.0	6.02	5.96	5.91	5.86	5.81	5.78	5.74
8.1	4.80	4.75	4.71	4.67	4.64	4.61	4.59

8.2	3.83	3.80	3.76	3.74	3.71	3.69	3.67
8.3	3.06	3.03	3.01	2.99	2.97	2.96	2.94
8.4	2.45	2.43	2.41	2.40	2.38	2.37	2.36
8.5	1.96	1.95	1.94	1.93	1.92	1.91	1.91
8.6	1.58	1.57	1.56	1.55	1.55	1.54	1.54
8.7	1.27	1.26	1.26	1.25	1.25	1.25	1.25
8.8	1.03	1.02	1.02	1.02	1.02	1.02	1.02
8.9	0.833	0.832	0.831	0.831	0.832	0.834	0.838
9.0	0.681	0.681	0.681	0.682	0.684	0.688	0.692

Temperature (T) in degrees Celcius

pH	T = 14.0	T = 15.0	T = 16.0	T = 17.0	T = 18.0	T = 19.0	T = 20.0
6.5	24.6	24.5	24.3	24.2	24.0	23.9	23.8
6.6	23.9	23.8	23.6	23.5	23.3	23.3	23.2
6.7	23.1	23.0	22.8	22.7	22.6	22.5	22.4
6.8	22.2	22.0	21.9	21.8	21.7	21.6	21.5
6.9	21.1	21.0	20.8	20.7	20.6	20.5	20.4
7.0	19.9	19.7	19.6	19.5	19.4	19.3	19.2
7.1	18.5	18.4	18.3	18.2	18.1	18.0	17.9
7.2	17.1	16.9	16.8	16.8	16.7	16.6	16.5
7.3	15.5	15.4	15.3	15.2	15.2	15.1	15.1
7.4	13.9	13.9	13.8	13.7	13.6	13.6	13.5
7.5	12.4	12.3	12.2	12.2	12.1	12.1	12.0
7.6	10.8	10.8	10.7	10.7	10.6	10.6	10.5
7.7	9.37	9.31	9.26	9.22	9.18	9.15	9.12
7.8	8.02	7.97	7.93	7.90	7.87	7.84	7.82
7.9	6.79	6.75	6.72	6.69	6.67	6.65	6.64
8.0	5.71	5.68	5.66	5.62	5.61	5.60	5.74
8.1	4.56	4.54	4.53	4.51	4.50	4.49	4.49
8.2	3.65	3.64	3.63	3.62	3.61	3.61	3.61
8.3	2.93	2.92	2.92	2.91	2.91	2.91	2.91
8.4	2.36	2.35	2.35	2.35	2.35	2.35	2.36

8.5	1.90	1.90	1.90	1.90	1.90	1.91	1.92
8.6	1.54	1.54	1.54	1.55	1.56	1.56	1.57
8.7	1.25	1.25	1.26	1.26	1.27	1.28	1.29
8.8	1.02	1.03	1.03	1.04	1.05	1.06	1.07
8.9	0.842	0.847	0.853	0.861	0.870	0.880	0.891
9.0	0.698	0.704	0.711	0.720	0.729	0.740	0.752

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Table 4. Average 30-Day Concentration of Total Ammonia Nitrogen for Protection of Aquatic Life (mg/L of Nitrogen)

Temperature (T) in degrees Celcius

pH	T = 0.0	T = 1.0	T = 2.0	T = 3.0	T = 4.0	T = 5.0	T = 6.0
6.5	2.08	2.05	2.02	1.99	1.97	1.94	1.92
6.6	2.08	2.05	2.02	1.99	1.97	1.94	1.92
6.7	2.08	2.05	2.02	1.99	1.97	1.94	1.92
6.8	2.08	2.05	2.02	1.99	1.97	1.94	1.92
6.9	2.08	2.05	2.02	1.99	1.97	1.94	1.92
7.0	2.08	2.05	2.02	1.99	1.97	1.94	1.92
7.1	2.08	2.05	2.02	1.99	1.97	1.94	1.92
7.2	2.08	2.05	2.02	1.99	1.97	1.94	1.92
7.3	2.08	2.05	2.02	1.99	1.97	1.94	1.92
7.4	2.08	2.05	2.02	2.00	1.97	1.95	1.92
7.5	2.08	2.05	2.02	2.00	1.97	1.95	1.92
7.6	2.09	2.05	2.03	2.00	1.97	1.95	1.93
7.7	2.09	2.05	2.03	2.00	1.98	1.95	1.93
7.8	1.78	1.75	1.73	1.71	1.69	1.67	1.65
7.9	1.50	1.48	1.46	1.44	1.43	1.41	1.39
8.0	1.26	1.24	1.23	1.21	1.20	1.18	1.17
8.1	1.00	0.989	0.976	0.963	0.952	0.942	0.932
8.2	0.799	0.788	0.777	0.768	0.759	0.751	0.743

8.3	0.636	0.628	0.620	0.613	0.606	0.599	0.594
8.4	0.508	0.501	0.495	0.489	0.484	0.479	0.475
8.5	0.405	0.400	0.396	0.381	0.387	0.384	0.380
8.6	0.324	0.320	0.317	0.313	0.310	0.308	0.305
8.7	0.260	0.257	0.254	0.251	0.249	0.247	0.246
8.8	0.208	0.206	0.204	0.202	0.201	0.200	0.198
8.9	0.168	0.166	0.165	0.163	0.162	0.161	0.161
9.0	0.135	0.134	0.133	0.132	0.132	0.131	0.131

Temperature (T) in degrees Celcius

pH	T = 7.0	T = 8.0	T = 9.0	T = 10.0	T = 11.0	T = 12.0	T = 13.0
6.5	1.90	1.88	1.86	1.84	1.82	1.81	1.80
6.6	1.90	1.88	1.86	1.84	1.82	1.81	1.80
6.7	1.90	1.88	1.86	1.84	1.83	1.81	1.80
6.8	1.90	1.88	1.86	1.84	1.83	1.81	1.80
6.9	1.90	1.88	1.86	1.84	1.83	1.81	1.80
7.0	1.90	1.88	1.86	1.84	1.83	1.81	1.80
7.1	1.90	1.88	1.86	1.84	1.83	1.81	1.80
7.2	1.90	1.88	1.86	1.85	1.83	1.81	1.80
7.3	1.90	1.88	1.86	1.85	1.83	1.82	1.80
7.4	1.90	1.88	1.87	1.85	1.83	1.82	1.80
7.5	1.91	1.88	1.87	1.85	1.83	1.82	1.81
7.6	1.91	1.89	1.87	1.85	1.84	1.82	1.81
7.7	1.91	1.89	1.87	1.86	1.84	1.83	1.81
7.8	1.63	1.62	1.60	1.59	1.57	1.56	1.55
7.9	1.38	1.36	1.35	1.34	1.33	1.32	1.31
8.0	1.16	1.15	1.14	1.13	1.12	1.11	1.10
8.1	0.922	0.914	0.906	0.899	0.893	0.887	0.882
8.2	0.736	0.730	0.724	0.718	0.714	0.709	0.706
8.3	0.588	0.583	0.579	0.575	0.571	0.568	0.566
8.4	0.471	0.467	0.464	0.461	0.458	0.456	0.455
8.5	0.377	0.375	0.372	0.370	0.369	0.367	0.366

8.6	0.303	0.301	0.300	0.298	0.297	0.297	0.296
8.7	0.244	0.243	0.242	0.241	0.241	0.240	0.240
8.8	0.197	0.197	0.196	0.196	0.196	0.196	0.196
8.9	0.160	0.160	0.160	0.160	0.160	0.161	0.161
9.0	0.131	0.131	0.131	0.131	0.132	0.132	0.133

Temperature (T) in degrees Celcius

pH	T = 14.0	T = 15.0	T = 16.0	T = 17.0	T = 18.0	T = 19.0	T = 20.0
6.5	1.78	1.77	1.64	1.52	1.41	1.31	1.22
6.6	1.78	1.77	1.64	1.52	1.41	1.31	1.22
6.7	1.78	1.77	1.64	1.52	1.41	1.31	1.22
6.8	1.78	1.77	1.64	1.52	1.42	1.32	1.22
6.9	1.78	1.77	1.64	1.53	1.42	1.32	1.22
7.0	1.79	1.77	1.64	1.53	1.42	1.32	1.22
7.1	1.79	1.77	1.65	1.53	1.42	1.32	1.23
7.2	1.79	1.78	1.65	1.53	1.42	1.32	1.23
7.3	1.79	1.78	1.65	1.53	1.42	1.32	1.23
7.4	1.79	1.78	1.65	1.53	1.42	1.32	1.23
7.5	1.80	1.78	1.66	1.54	1.43	1.33	1.23
7.6	1.80	1.79	1.66	1.54	1.43	1.33	1.24
7.7	1.80	1.79	1.66	1.54	1.44	1.34	1.24
7.8	1.54	1.53	1.42	1.32	1.23	1.14	1.07
7.9	1.31	1.30	1.21	1.12	1.04	0.970	0.904
8.0	1.10	1.09	1.02	0.944	0.878	0.818	0.762
8.1	0.878	0.874	0.812	0.756	0.704	0.655	0.611
8.2	0.703	0.700	0.651	0.606	0.565	0.527	0.491
8.3	0.564	0.562	0.523	0.487	0.455	0.424	0.396
8.4	0.453	0.452	0.421	0.393	0.367	0.343	0.321
8.5	0.366	0.365	0.341	0.318	0.298	0.278	0.261
8.6	0.296	0.296	0.277	0.259	0.242	0.227	0.213
8.7	0.241	0.241	0.226	0.212	0.198	0.186	0.175
8.8	0.197	0.198	0.185	0.174	0.164	0.154	0.145

8.9	0.162	0.163	0.153	0.144	0.136	0.128	0.121
9.0	0.134	0.135	0.128	0.121	0.114	0.108	0.102

1. The average of the measured values must be less than the average of the corresponding individual values.

2. Each measured value is compared to the corresponding individual values. No more than one in five of the measured values can be greater than 1.5 x the corresponding criteria values.

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Preface

The MINISTRY OF ENVIRONMENT, LANDS AND PARKS (now called Ministry of Water, Land and Air Protection) develops province-wide ambient water quality guidelines for variables that are important in the surface waters of British Columbia. This work has the following goals:

1. to provide guidelines for the evaluation of data on water, sediment and biota
2. to provide guidelines for the establishment of site-specific ambient water quality objectives

Ambient water quality objectives for specific waterbodies will be based on the guidelines and also consider present and future uses, waste discharges, hydrology/limnology/oceanography, and existing background water quality. The process for establishing water quality objectives is more fully outlined in *Principles for Preparing Water Quality Objectives in British Columbia*, copies of which are available from the Water Quality Section of the Water, Air and Climate Change Branch.

Neither guidelines nor objectives which are derived from them, have any legal standing. The objectives, however, can be used to calculate allowable limits or levels for contaminants in waste discharges. These limits are set out in waste management permits and thus have legal standing. The objectives are not usually incorporated as conditions of the permit.

The definition adopted for a guideline is:

A maximum and/or a minimum value for a physical, chemical or biological characteristic of water, sediment or biota, which should not be exceeded to prevent specified detrimental effects from occurring to a water use, including aquatic life, under specified environmental conditions.

The guidelines are province-wide in application, are use-specific, and are developed for some or all of the following specific water uses:

- raw drinking, public water supply and food processing
- aquatic life and wildlife

- agriculture (livestock watering and irrigation)
- recreation and aesthetics
- industrial (water supplies)

The guidelines are set after considering the scientific literature, guidelines from other jurisdictions, and general conditions in British Columbia. The scientific literature gives information on the effects of toxicants on various life forms. This information is not always conclusive because it is usually based on laboratory work which, at best, only approximates actual field conditions. To compensate for this uncertainty, guidelines have built-in safety factors which are conservative but reflect natural background conditions in the province.

The site-specific water quality objectives are, in most cases, the same as guidelines. However, in some cases, such as when natural background levels exceed the guidelines, the objectives could be less stringent than the guidelines. In relatively rare instances, for example if the resource is unusually valuable or of special provincial significance, the safety factor could be increased by using objectives which are more stringent than the guidelines. Another approach in such special cases is to develop site-specific guidelines by carrying out toxicity experiments in the field. This approach is costly and time-consuming and therefore seldom used.

Guidelines are subject to review and revision as new information becomes available, or as other circumstances dictate.

The guidelines apply to the ambient raw water source before it is diverted or treated for domestic use.

The Ministry of Health regulates the quality of water for domestic use after it is treated and delivered by a water purveyor.

Guidelines relating to public health at bathing beaches are the same as those used by the Ministry of Health which regulates the recreation and aesthetic use.

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Recommended Guidelines

These criteria are based on a detailed analysis given in a technical document and are summarized in the Tables. The criteria are consistent with the Canadian Water Quality Guidelines (CCREM Guidelines) issued by the Canadian Council of Resource and Environment Ministers (1986), except as noted.

Nitrate, nitrite, and ammonia are the major inorganic nitrogen compounds occurring in surface waters. There is little environmental information on other compounds, both inorganic and organic, which are minor constituents or do not appear to affect water uses. These are therefore not included in the report at this time.

Drinking Water (Includes Food Processing Water)

For drinking water, high nitrate concentrations have been identified as a problem for infants. Nitrate can be converted to nitrite which combines with hemoglobin in the blood to form methemoglobin which does not absorb oxygen. With reduced capacity of the blood to absorb oxygen, death from lack of oxygen can result. Many agencies have specified maximum acceptable concentrations for nitrate or nitrate plus nitrite in drinking water and there is a general consensus that 10 mg/L (as N) represents a level of adequate protection. This well established level is proposed as the criterion for nitrate in drinking water for British Columbia.

The criterion for British Columbia which is proposed is a maximum of 10 mg/L nitrate + nitrite (as N).

There is also a general consensus with regard to nitrite among other agencies, and no recent scientific evidence to the contrary, that less than 1 mg/L nitrite (as N) represents a concentration which will provide protection against adverse effects in humans in drinking water supplies.

The criterion for British Columbia which is proposed is a maximum of 1 mg/L nitrate + nitrite (as N).

Establishing a criterion for ammonia in drinking water is more difficult. Although a number of other agencies have specified ammonia concentrations intended to provide acceptable drinking water, there now seems to be a very poor basis for the concentrations proposed. There does not seem to be sufficient data to define an ammonia concentration at which problems such as taste and odour, interference with chlorine disinfection, or any health effects occur. Consequently, no criterion for ammonia in drinking water supplies is proposed.

Aquatic Life (Freshwater, Marine and Estuarine)

In the literature, there has been a much more detailed examination of the response to nitrate, nitrite, and ammonia by freshwater biota, particularly fish, than by marine biota. Studies concerning estuarine biota are almost totally absent. As a consequence, the data on which to base criteria are much better for freshwater than marine water. Since virtually no data exist for nitrogen toxicity in estuarine environments, no specific criteria are suggested. It is proposed that the more stringent of freshwater and marine criteria should be used for estuaries. For these criteria the maximum concentration is designed to protect aquatic life against acutely toxic effects and the 30-day average against chronic effects. The 30-day average should be calculated from at least five weekly samples.

For freshwater studies there has been different amounts of research into the aquatic toxicology of the three forms of nitrogen. Nitrate has been the subject of few investigations due to its relatively low toxicity.

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Based on the information available, a criterion of 200 mg/L nitrate (as N) is recommended as a maximum concentration and 40 mg/L nitrate (as N) as a 30-day average.

There are no CCREM Guidelines for nitrate for freshwater aquatic life.

Nitrite has been shown to be quite toxic to some groups of fish, particularly salmonids, and consequently more investigations have been done.

> ***On the basis of literature reports, a criterion of 0.020 mg/L (as N) is recommended as a mean concentration over a 30-day period for low chloride water, and a maximum concentration of 0.060 mg/L (as N) is recommended.***

Allowable concentrations increase with ambient concentrations of chloride, as shown in the Tables. The CCREM Guidelines specify a maximum of 0.06 mg/L for all chloride concentrations. The recommended criteria vary with chloride concentration to reflect the marked influence of chloride on nitrite toxicity, and average criteria have also been recommended to provide adequate protection to the salmonids prevalent in British Columbia, particularly at low chloride concentrations.

Ammonia has been the subject of intensive investigation and there is thus an excellent background on which to base a criterion. Because ammonia has been investigated for a long period, increasingly sophisticated and accurate criteria are being derived. Ammonia criteria have evolved from a single value to tabular criteria relating toxicity to important physical or other interactive factors which affect toxicity. Two factors which are important to the toxicity of ammonia to aquatic organisms are the pH and temperature of the water environment. The pH and temperature affect the amount of un-ionized ammonia which is the form most toxic to aquatic life.

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> ***The Tables give the criteria recommended for maximum allowable concentrations of ammonia and for longer-term (30 day) allowable concentrations.***

These criteria are similar to those developed by the US Environmental Protection Agency (EPA). The CCREM Guidelines adopted the EPA average criteria as maximum values, which in British Columbia's opinion is unnecessarily restrictive.

For marine studies, less information is available on which to base criteria. For nitrate and nitrite, insufficient data are available to propose any criteria.

NOTE: The marine ammonia criteria found in this document have been replaced by newer values found in the document *Ambient Water Quality Guidelines for Ammonia to Protect Marine Aquatic Life.*

> ***For ammonia, a maximum concentration of 2.5 mg/L (as N) and a 30 day average concentration of 1.0 mg/L (as N) are***

recommended.

There are no CCREM Guidelines for marine aquatic life. For estuarine conditions, the freshwater criteria apply. Increasing salinity decreases ammonia toxicity to a slight degree so some marginal additional protection is afforded.

Irrigation and Livestock Watering

Water with excessive amounts of ammonia may affect agricultural uses such as irrigation or water supplied to livestock. Insufficient information is available to establish a criterion for nitrogen in irrigation water since an allowable concentration would be dependent on soil type, irrigation rate, and other factors. The proposed criteria for livestock watering exclude ammonia since few data exist.

For nitrate or nitrate plus nitrite, a maximum concentration of 100 mg/L (as N) is recommended and for nitrite alone a maximum of 10 mg/L (as N). The same concentrations are recommended for waters which might be used by wildlife as a drinking water supply.

There are no CCREM Guidelines for wildlife.

Recreation and Aesthetics

This is a water use for which high concentrations of nitrate, nitrite or ammonia are not likely to cause any direct problems in terms of body contact or visual deterioration. The more likely problem would be eutrophication-related problems when high concentrations of nitrogen (and accompanying phosphorus) cause heavy accumulations of algae. However, to protect recreational users who may ingest water, it is recommended that the drinking water criteria should apply to waters used for recreation.

The criteria for British Columbia which is proposed is a maximum of 10 mg/L nitrate + nitrite (as N). The criterion for British Columbia which is proposed is a maximum of 1 mg/L nitrite (as N).

There are no CCREM Guidelines for nitrogen for recreation.

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Application of Guidelines

Most of the criteria proposed require no additional explanation for their use. However, the table of ammonia criteria values for evaluation of chronic toxicity does require additional explanation for its application. The designated sampling period is 30 days and it is intended that at least five samples would be obtained. In addition to ammonia, each sample must be measured for pH and temperature. The temperature is that of the water in the field, and the pH is the laboratory pH at the time of analysis, although field pH is also acceptable if truly accurate measurements can be obtained.

The average measured concentration is calculated as an arithmetic mean. Using the individual temperature and pH values, the corresponding criteria values are obtained from the table. A mean of these criteria values is compared to the mean of the measured ammonia values. If the mean value for measured total ammonia exceeds the mean criteria value, the criteria would then be considered to be exceeded. If the mean value does not exceed the mean criteria value, it is still necessary to compare individual criteria to corresponding analytical results to ascertain whether or not more than 20% of the measured values exceed the mean criteria value by more than 150%. If more than 20% of the measured values do exceed the mean criteria by 150%, the criteria is exceeded even if the measured mean is less than the mean criteria value. This provision restricts the occurrence of fluctuating concentrations which can be more detrimental to aquatic life than a steady concentration.

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MINISTRY OF ENVIRONMENT AND PARKS
PROVINCE OF BRITISH COLUMBIA

WATER QUALITY ASSESSMENT AND OBJECTIVES
FRASER-DELTA AREA
BOUNDARY BAY AND ITS TRIBUTARIES

TECHNICAL APPENDIX

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1. INTRODUCTION

1.1 BACKGROUND

The Ministry of Environment and Parks is preparing water quality assessments and objectives for priority waterbodies. This report describes the water quality of the Serpentine, Nicomekl, and Little Campbell Rivers and Boundary Bay, all located within the Fraser-Delta area (Figures 1 and 2). The main purpose of this review was to develop provisional water quality objectives for the Fraser-Delta area for use by the Greater Vancouver Regional District in preparation of a Liquid Waste Management Plan. Presented within this report are data collected to about September 1986. Two additional reports evaluating water quality within the Fraser-Delta area have been prepared. One report dealt with the Fraser River and some tributaries from Hope to Kanaka Creek, while the other dealt with the Fraser River and some of its tributaries from Kanaka Creek to Sturgeon Banks.

The Ministry of Environment and Parks is developing criteria for water quality constituents of concern in British Columbia. Until criteria for a constituent have been approved by the Ministry, working criteria will be used. The criteria mentioned in this report are working criteria, unless noted as being provincial criteria. The provincial criteria, when approved, may be different from the working criteria used in this report.

Some of the data summarized are given with mean values, but often with median values. The reason for this apparent inconsistency is that many data were collected over long time periods during which many detection limits may have existed. The authors have used whichever statistic has more meaning. Median values are always reported for coliforms and pH.

1.2 ORGANIZATION

The sub-basins of the Fraser-Delta area examined in this report are Boundary Bay and its three main tributaries: the Serpentine, Nicomekl, and Little Campbell Rivers.

1.2.1 LITTLE CAMPBELL RIVER

This river, approximately 30 km in length, flows in a westerly direction from Aldergrove Lake Park to Semiahmoo Bay (Figure 5). The 65 km^2 drainage basin includes four tributaries: Fergus Creek and Sam Hill Creek, which enter the river from the north, and Jacobson Creek and Highland Creek which enter from the south.

1.2.2 SERPENTINE AND NICOMEKL RIVERS

These two rivers share a main valley, a former embayment of the sea, which extends 11 km eastward from Mud Bay to Cloverdale and varies in width from 4 km to 5 km(2).

The Nicomekl River, approximately 34 km in length, extends from Clayton and Langley southwest through the main valley to its mouth in Mud Bay. Anderson and Murray Creeks are the two major tributaries within the 149 km^2 drainage basin. These creeks are approximately 15 km and 12 km in length, respectively.

The Serpentine River is approximately 35 km in length. Major tributaries of this river are Latimer, Mahood (Bear), and Hyland Creeks which drain a northern extension of the main valley bounded by Clayton and Newton Uplands. The drainage basin area of the Serpentine River is approximately 116 km^2.

1.2.3 BOUNDARY BAY

Boundary Bay, including its northeasterly extension of Mud Bay and its eastern section called Semiahmoo Bay, is located on the south side of the Fraser-Delta area approximately 19 km south from the City of Vancouver. It is 15 km long and 4 km wide, covering an area of 6 090 hectares. The Bay is rectangular in shape and faces southeast onto the southern Strait of Georgia.

2. LITTLE CAMPBELL RIVER

This 65 km^2 drainage basin, extending from the Langley Uplands westward to Semiahmoo Bay, is primarily an agricultural area with some recreational and urban development. The Little Campbell River has four major tributaries which drain the surrounding highlands (Figures 3a, 5). Fergus Creek flows southerly and is situated east from White Rock. It is 7.2 km long with a drainage area of 9 km^2. Sam Hill Creek, near Hazelmere, also flows southerly, has a drainage area of 3 km^2 and is 4 km in length. Both Jacobson Creek and Highland Creek originate in the highlands of northwest Washington State, flow northwesterly to the Little Campbell River, and have similar drainage areas (4.4 km^2 and 4.8 km^2, respectively). Jacobson Creek is 1 km longer than Highland Creek (5.5 km and 4.5 km, respectively).

The Little Campbell River watershed was logged early in the century and a lumber mill and log booming ground existed at the river mouth until 1930. The watershed is extensively farmed.

2.1 HYDROLOGY

Two flow measuring sites were located within this drainage basin (Figure 3). Station 08MH059, near White Rock on the Little Campbell River, operated between 1961 and 1964. An annual discharge of 22 500 dam^3 was recorded in 1962 and 36 600 dam^3 in 1963 (daily discharge ranged from 0.0 m^3/s to 14.2 m^3/s with a mean flow of 0.94 m^3/s). The lowest recorded flows typically occurred between June and October (mean daily discharge ranged from 0.06 m^3/s to 0.32 m^3/s), with maximum flows occurring from November to January and in March (daily discharge ranged from 0.23 m^3/s to 14.2 m^3/s; mean daily discharge ranged from 1.01 m^3/s to 4.02 m^3/s).

Station 08MH0123, upstream from the confluence of Sam Hill Creek on the Little Campbell River, had mean monthly flows recorded from May to September in 1966. Values ranged from 0.1 m^3/s in August and September, to 0.29 m^3/s in May.

2.2 WATER USES

The issuance of water licences was discontinued in the period from 1959 to 1969 when the river was declared as being fully subscribed(2). Forty-two licenced water withdrawals are located within the Little Campbell drainage basin (Figure 3a). The total annual permitted withdrawal from this system is 1 027 dam³ of which 66.9% is used for irrigation (686 dam³ at 26 sites), 23.6% for stock watering (242 dam³ at 7 sites), 6.8% for industrial use (70 dam³ at 4 sites), 2.4% for land improvement (24 dam³ at 3 sites), and 0.5% for domestic use (5 dam³ at 2 sites). Water withdrawals classed as industrial are used for irrigating golf courses and watering lawns. One of the stock watering licenses relates to a turkey farm. Water withdrawals for land improvements were permitted for pond creation on the Little Campbell River, a fish pond on Ellen Creek, and a fish pond and ladder on Fergus Creek. Swimming occurs in sections of the Little Campbell River near the mouth and adjacent to the Hazelmere Riverside Campground (see Section 2.3.3.2).

Steelhead and cutthroat trout utilize the Little Campbell River system, which ranks fifth or sixth in steelhead angling importance in the Lower Mainland Region.

Spawning of coho salmon in the Little Campbell basin (Figure 5) predominantly occurs between 7 km to 15 km upstream from its mouth and in the lower reaches of Sam Hill Creek, Fergus Creek, and in an unnamed creek 1.2 km upstream from the mouth of the river(42). Scattered spawning also occurs throughout the upper river reaches. Spawning of chum salmon takes place 7 km to 20 km upstream from the mouth of the Little Campbell River. Jacobson and Highland Creeks have habitats which could be suitable for spawning and rearing coho and chum salmon (Figure 5).

The mean numbers of coho and chum returning to spawn (escapement) were calculated, in four-year intervals, for the period from 1962 to 1981. Escapement values for both species of salmon increased during the period from 1962 to 1976 with the largest increase occurring between 1972 and 1976

(Table 1). Mean annual escapement values for chum and coho salmon declined significantly after 1976.

2.3 WASTE DISCHARGES

Six small operations have permits to discharge effluents within this sub-basin. These can be divided into three categories: agricultural operations, gravel washing operations, and residential and recreational facilities. The locations of these waste discharges are referenced on Figure 3a by permit numbers which have been issued pursuant to the Waste Management Act. In addition, there are livestock-raising operations, extensive areas of cropland, and residential developments which contribute diffuse waste loadings to the basin.

The City of White Rock is served by municipal sewers which discharge to the Ladner trunk sewer. Within the drainage basin, there are 12 km^2 served by sewers, or a population of 54 000(79). It is projected that this will increase to 99 000 by 1996(80).

2.3.1 AGRICULTURAL OPERATIONS

There are two agricultural operations within this drainage basin under permit. These include a mink food processing plant (Section 2.3.1.1) and a feedlot operation (Section 2.3.1.2).

2.3.1.1 S.L. Scheves, Surrey (PE 2096)

This mink-food processing plant is located near the headwaters of an unnamed creek. It was issued a permit in 1975 to discharge effluent associated with processing mink feed. The permit allowed a maximum discharge of 0.91 m^3/d and the following maximum concentrations: 600 mg/L total solids, 55 mg/L suspended solids, and 580 mg/L BOD_5. Odours have been noted as a problem at this site. At present, effluent from this facility is being trucked away to another location. It therefore has no impact on nearby waterbodies.

When the treatment facility consisting of a lined aerated lagoon, septic tank, and seepage pits is installed, a receiving water monitoring program to evaluate the impact of the operation on the creek should be undertaken. It should include two stations (upstream and downstream) in the creek and a third site near the confluence of the creek and the Little Campbell River (to evaluate the impact on water quality within the river). Samples should be collected on a monthly basis for the first year with measurements of flow rates, ammonia, nitrate, nitrite, orthophosphorus, BOD_5, fecal coliforms, dissolved oxygen, temperature, and pH.

2.3.1.2 Border Feedlot Ltd.

This operation was located adjacent to PE 4256 (a gravel washing operation), near Jacobson Creek, and closed in 1984. The proliferation of filamentous algae and tubifix worms in Jacobson Creek was believed to be attributable to runoff from the feedlot operation. Further discussions related to this operation are included in Section 2.3.2.2 of this report.

Another operation under the same company name (located just downstream from Site 0300065) has been discussed in terms of its effect on the Little Campbell River in a report prepared by Swain and Alexander(3). Data had been collected due to fish kills which were suspected as having resulted from runoff from the operation(3). The data showed a significant increase in values between sites upstream and downstream from the operation on an adjacent creek for total organic carbon, ammonia, nitrate, nitrite, organic nitrogen, BOD_5, total phosphorus, orthophosphorus, and total fixed solids(3). No conclusions were drawn on what the impact was from this operation(3).

Waste discharges from feeding operations could be reduced through a system of collection ditches discharging to settling/exfiltration ponds. These ditches and settling ponds, with the capacity to contain runoff resulting from the large quantities of precipitation typical to this area, could also provide water for irrigation purposes. This could reduce the demand on river water for irrigation, and could permit the discharge of runoff at periods when nutrients in the runoff would have little impact on receiving water quality. The practicality of such a scheme would have to be determined.

2.3.1.3 Diffuse Sources

The Ministry of Agriculture and Fisheries, in cooperation with the B.C. Cattleman's Association, conducts the Beef Assurance Program. To be included in the program, an operator requires a minimum number of cattle (approximately 20 head). Records maintained under this program provide estimates of the average number of cows, calves, yearlings, and finishing cattle at each operation. From these estimates, nutrient loadings were calculated for each drainage basin using nutrient coefficients(78) for beef (Table 28). These estimates should only be used as indicators of nutrient loadings from diffuse sources owing to the nature of the program (voluntary, minimum size stipulation), variability in quantities and types of cattle at each operation due to market demand, cattle being only a portion of the agricultural sources within the drainage basin, and the uncertainty as to the proportion of nutrients generated that would actually enter surface water. Within this watershed, 53 km^2 (81.5%) of the land is used for mink, poultry, and dairy farms and cropland. This area has a population of 4 400. These types of operations are sources of nutrients to ground and surface waters and sediments to surface waters. However, information on which to determine the magnitude of such loadings to the receiving waters is beyond the scope of this report.

Records from the Beef Assurance Program identified three operations within the Little Campbell River watershed (one at the headwaters of Sam Hill Creek, two adjacent to the Little Campbell River). The largest operation is located on Sam Hill Creek with 300 yearlings and 50 finishing cattle. Facilities on the Little Campbell River near White Rock house 133 finishing cattle at the Border Feedlot operation on the Little Campbell River, and 29 cows and 27 calves at a site located in Hazelmere (Figure 3a).

The Border Feedlot operation near Jacobson Creek (Section 2.3.2.2) ceased operation in 1984.

Estimates of phosphorus and nitrogen loadings to the Little Campbell River are in Table 28. It was estimated that 11 060 kg of nitrogen and 860 kg of phosphorus could be generated annually by cattle in the watershed. Assuming 100% transport of these wastes to the river, which is unlikely to occur, nutrient levels in the Little Campbell River could be increased by the following based on varying river flows and arbitrarily chosen release periods.

Increase (mg/L) With Varying River Flows and Release Periods				
Characteristic	River Flow (m^3/s)	4 Weeks	2 Weeks	1 Week
Nitrogen	14.2	0.32	0.64	1.29
	4.02	1.14	2.27	4.55
	1.01	4.53	9.05	18.1
Phosphorus	14.2	0.025	0.05	0.10
	4.02	0.09	0.18	0.35
	1.01	0.35	0.70	1.41

These data indicate that phosphorus and nitrogen can be increased significantly at low flows, and even at peak flows when these nutrients likely would be released. Longer release periods and smaller rates of transmission would reduce these impacts. Actual riverine conditions are discussed in Section 2.4.3.

2.3.2 GRAVEL WASHING OPERATIONS

Two gravel washing operations exist in this watershed. They are operated by LaFarge Concrete and Border Sand and Gravel Ltd.

2.3.2.1 Lafarge Concrete Ltd. Surrey (PE 3331)

This operation was closed and dismantled in 1984.

This company operated a gravel washing operation about one km south from the Little Campbell River adjacent to Ellen Creek, which is a branch of Highland Creek (Figure 3a). It was issued a permit in 1974 for washwater from a truck wash and gravel washing operation. The quality of effluent discharged from these operations is indicated in Table 2. The gravel washwater was discharged to two settling ponds operated in series, each approximately 30.5 m x 18.3 m x 4.3 m deep. The effluent flowed by gravity to one settling pond, then through a pervious dyke to a second pond prior to being recycled. Make-up water was pumped from a deep well on the property.

The truck washwater was discharged to a settling pond approximately 9.1 m x 12.2 m x 4.3 m deep. The settled concrete residues were cleaned out regularly. Permit PE 3331 allowed the discharge of 3 241 m^3/d of truck washwater effluent to the settling pond.

The facility had on occasion discharged directly to Ellen Creek. The permit was amended in early 1980 to allow such a discharge only to occur at the discretion of the Regional Waste Manager.

Direct discharges from an operation of this nature could potentially contain large quantities of coarse and fine solids. However, the exact composition would depend upon volumes discharged and the settling pond from which the discharge took place. The result of such a discharge to Ellen Creek could be deleterious to resident fish populations in terms of scouring the creek bottom, increasing turbidity, or silting over spawning habitats.

2.3.2.2 Border Sand and Gravel Ltd. Langley (PE 4256)

This gravel wash and rock crushing operation is located about one km north from the International Border adjacent to Jacobson Creek. It was issued a permit (PE 4256) in 1976. The permit restricts the maximum flow rate to 2 273 m^3/d and the average flow rate to 1 964 m^3/d.

Effluent from the gravel washing operation flows into a small basin prior to entering an open ditch which discharges into an irregularly shaped settling pond. Clarified water is recycled back to the washing plant. Natural drainage from the pit area is collected and used as make-up water. Recent dyking has reduced the direct discharge to nearby Jacobson Creek.

Border Feedlot (Section 2.3.1.2) was located adjacent to Border Sand and Gravel Ltd. Intermittent discharges from the sand and gravel operation flowed through the feedlot to the creek. Historically, effluent discharged from the pond contained as much as 7 200 mg/L dissolved solids and 2 000 mg/L suspended solids. Remedial works to collect natural runoff at the gravel pit have been installed. Runoff from this operation only occurs during periods of high precipitation or when the system malfunctions. The feedlot operation was closed in 1984.

It is recommended that a one-year monitoring program to assess the impact of the Border Sand and Gravel Ltd. feedlot on Jacobson Creek be undertaken if the feedlot should reopen. Effluent and receiving water monitoring should coincide with precipitation events. Receiving water quality sites adjacent to these operations should be located 100 m upstream and downstream. Samples should be collected seven times a year (once a month during periods of low flow, and in October, November, and January). In addition, to evaluate the eventual impact on Jacobson Creek and the Little Campbell River, four samples should be collected in June, August, October, and January, at a site on Jacobson Creek and the Little Campbell River 100 m upstream from their confluence, and at Site 0301305 on the Little Campbell River downstream from the confluence. A site near the mouth of Ellen Creek would also be necessary. Field measurements should be made for pH, temperature, dissolved oxygen, and flow rate. Laboratory measurements should include ammonia, nitrate, nitrite, kjeldahl nitrogen, total dissolved phosphorus, total phosphorus, suspended and dissolved solids, fecal coliforms, and organic carbon.

2.3.3 RECREATIONAL AND RESIDENTIAL FACILITIES

2.3.3.1 M. Gurtitz Trailer Park, Langley (PE 225, PE 236)

This operation is located about one km north from the Little Campbell River. Permit PE 225, issued for a single dwelling and 32-unit mobile home park in 1968, allows the discharge of 23.2 m^3/d of treated domestic sewage to a tile field after treatment in a 46.4 m^3 septic tank. The tile field is in a sandy gravel soil with approximately 15 cm of organic cover. The percolation rate is 0.2 min/cm.

Permit PE 236, issued in 1970 for a 34-unit mobile home park in Langley, allowed the discharge of 23.2 m^3/d. Treatment and disposal were identical to that cited for the 32-unit mobile home and single dwelling (PE 225).

Effluent from these trailer parks will likely have no measurable impact on the water quality of the Little Campbell River due to the small quantities involved, the fact that the effluents are discharged to soil adsorption systems, and the distance from the river.

2.3.3.2 Hazelmere Riverside Campground, Surrey (PE 1558)

This facility is located just south from the Little Campbell River and about six km upstream from White Rock. It has operated under permit since 1972. Sewage is treated in two septic tanks with 24-hour retention, prior to final disposal in two separate tile fields with a total of 1 500 m of tile located 30 m from the river. The quality of the septic tank effluent is indicated in Table 3. Values are typical of those expected from a septic tank. The permit restricts the flow of treated domestic sewage to a maximum 22.7 m^3/d between May 1 and September 30 of each year.

Three fecal coliform samples were collected in the river upstream at Site 0301305 and at the downstream Site 0301306 between 1977 and 1979. These are listed below:

	Fecal Coliforms (MPN/100 mL) Upstream	 Downstream
1977	310	490
1977	330	460
1979	540	240

The data were inconclusive, but may have exceeded working criteria for primary-contact recreation and irrigation of 200/100 mL as a geometric mean and 400/100 mL as a 90th percentile(11,30). Complete water treatment would be necessary prior to use for drinking or stock watering(30). These high upstream values may be attributed to upland activities. Eleven water withdrawals are licenced for this portion of the river, including one for stock watering, and ten for irrigation. Swimming occurs in the river adjacent to the campground.

Two sampling programs are proposed for the Hazelmere Riverside Campground. First, a program is proposed to evaluate the water quality of the Little Campbell River adjacent to this facility during periods of operation (May 1 to September 30). Once a week, a discrete sample from the middle of the river within the recreational (bathing) area should be analyzed for fecal coliforms. The geometric mean for five of these samples should not exceed 200 fecal coliforms/100 mL. Resampling should occur as soon as possible when any sample exceeds 400 fecal coliforms/100 mL. Second, a program to delineate any influence of the tile fields on the water quality in the Little Campbell River is proposed. Upstream and downstream river monitoring should be conducted monthly from May through September during one year. Measurements should be made for pH, dissolved oxygen, temperature, ammonia, nitrate, nitrite, orthophosphorus, and fecal coliforms. If substantial changes are measured from upstream to downstream, some groundwater monitoring should be undertaken, the exact program to be established at that time.

2.3.3.3 Sunnyside Villas Society (PE 5478)

This permit was issued to a senior citizens housing complex four km north from the City of White Rock in 1980 (Figure 3). The complex consists of a main lodge (24 rooms), twelve cottages, and eight bachelor facilities. Sewage from this operation is treated in an aerobic batch-type secondary treatment plant which discharges to three ground disposal fields. There is a total of 625 m² of tile with a second field of similar area for back-up. A percolation test conducted in the area measured water moving at 7.4 min/cm. The interceptor ditch from these fields enters an open ditch adjacent to 152nd Street which is connected to the White Rock stormwater sewer.

A permit issued pursuant to the Waste Managment Act limits concentrations of BOD_5 (45 mg/L) and total suspended solids (60 mg/L) in the effluent discharged from the treatment plant to the tile field. Single effluent data from this operation for the period 1983-1985 are presented below.

Permit 5478
SUNNYSIDE VILLAS SOCIETY

YEAR	TOTAL SUSPENDED SOLIDS	BOD_5
1983	8	< 10
1984	31	< 10
1985	30	< 10

These concentrations, the discharge to ground, and the distance between the discharge point and the Little Campbell River indicate that there likely would not be an impact on water quality within the Little Campbell River from this operation.

2.3.3.4 Del-Van Construction Ltd. (PE 4645)

This 107-unit rental mobile home park is located upstream from Jacobson Creek. It was issued a permit in 1977 for the discharge of treated domestic sewage at a maximum rate of 123 m^3/d, and maximum concentrations of 20 mg/L BOD_5 and 30 mg/L suspended solids to dual tile fields located 137 m from the Little Campbell River.

The sewage is treated in two batch-type package treatment plants operated in parallel, each with a capacity of 68.2 m^3/d. Treated batches are discharged alternately at a rate of 7.25 m^3/h to a tank which discharges to an upflow graded-media filter. The filter is cleaned by flushing, after which the wash is returned to the head of the treatment plant.

In order that the tile fields can be dosed, a constant flow from the filter is collected in a second tank for pumping through the fields. This effluent may affect the water quality (phosphorus and nitrogen levels) of the Little Campbell River since it is discharged to a soil adsorption system 137 m from the river.

2.3.3.5 Diffuse Sources

Residential diffuse sources of wastewater include septic tank tile fields and urban stormwater runoff from a small area of White Rock.

In Section 2.3.1.3, it was estimated that 4 400 people live in agricultural areas within the watershed, and thus likely use septic tanks and tile fields for wastewater disposal. Assuming 4 people per household, there are approximately 1100 septic tank tile-field systems in the drainage area. The impact that each system would have on the Little Campbell River would depend upon local soil conditions, the distance to the river, and the quantity of sewage discharged. It is expected that septic tanks and tile fields contribute some loadings of nitrogen, phosphorus, and fecal coliforms, but estimation of these loadings is not possible with the available data. This would require an examination of local soils and land use, as well as groundwater analyses.

Urban stormwater inputs into the Little Campbell River from White Rock would be small in comparison to the total amount of stormwater runoff from

White Rock. Swain[24] indicated that urban runoff from residential areas could contribute loadings of fecal coliforms, lead, zinc, and PCBs.

2.4 WATER QUALITY AND PROPOSED PROVISIONAL WATER QUALITY OBJECTIVES

An assessment of water quality data collected until 1979 at a site on the Little Campbell River near the mouth (0300065) was conducted as part of a report by Swain and Alexander[3]. This, in conjunction with an examination of data collected from 1979 to 1986 at Site 0300065 and data from a site near the headwaters (0300066), provides the basis for the following assessment of the Little Campbell drainage basin. Locations of the water quality sites are shown in Figure 3a, and the data are summarized in Tables 4 and 5.

Present water uses which should be protected in the Little Campbell basin include irrigation, livestock watering, aquatic life, wildlife, and primary-contact recreation.

Maximum values for specific conductivity[57], chloride[53], sodium[55], potassium[75] and sulphate[55] were below the criteria for all water uses, while arsenic values were below a high detection limit (0.25 mg/L) at both sites on the Little Campbell River. These constituents are not discussed further in the following sections.

2.4.1 pH AND BUFFERING CAPACTIY

The pH at Site 0300066 was generally more acidic than at Site 0300065 further downstream (Site 0300065 pH range: 6.9 to 8.6, median 7.55; site 0300066 pH range: 6.5 to 7.0, median 6.8). Values for pH at Sites 0300065 and 0300066 generally increased during periods of low flow when temperature and ammonia values were also high. Values for pH at both sites generally were within the criteria ranges for the protection of aquatic life (6.5-9.0)[31] and for drinking water (6.5 to 8.5)[7]. One sample collected in 1982 at Site 0300065 had a pH value (8.6) which slightly exceeded the criteria for drinking water.

Since the pH values generally meet the more restrictive drinking water criteria, and lower pH values can prevent the formation of toxic concentrations of ammonia, the drinking water criteria are proposed as the provisional objective for pH. Specifically, the objective is that the pH should be in the range of 6.5 to 8.5 at any point in the Little Campbell River basin, except in the initial dilution zones of effluents. If upstream values are outside this range, there should be no change from upstream. These initial dilution zones are defined as occupying less than 50 percent of river width, being no further than 100 m downstream from any discharge point or series of discharge points, and extending from the bed of the river to the surface.

Mean total alkalinity values at both sites were close to 40 mg/L, indicating a moderate buffering capacity of the river to acidic inputs. Low alkalinity values (<25 mg/L) occurred during periods of low flow, high temperatures and pH, and high nitrogen concentrations at Site 0300066. The working water quality criterion of a minimum alkalinity of 20 mg/L for the protection of aquatic life(4) was generally met.

2.4.2 HARDNESS AND METALS

The mean total hardness values at both Sites 0300065 and 0300066 were approximately 30 mg/L. Water with hardness values of this magnitude would be classified as soft (<75 mg/L as $CaCO_3$).

2.4.2.1 Metal Values in the Water Column

Metal values were usually lower than the working water quality criteria for the protection of aquatic life, and/or below detection limits. Exceptions to this were values for total aluminum, copper, iron, lead, and manganese. For these metals, higher values were associated with elevated suspended solids.

Total aluminum was measured at both sites on two occasions in 1982. Values at Site 0300066 were less than the working criterion for the protection of aquatic life of 0.10 mg/L(5). However, both samples from Site 0300065 contained aluminum concentrations higher than this working criterion. No water quality objective is proposed for aluminum since background values seem high, which cannot be controlled.

Total copper values at Site 0300066 were all less than the detection limit of 0.01 mg/L; however, it cannot be determined if they were less than the working criterion of 0.002 mg/L for the protection of aquatic life(6). Seven samples collected between 1979 and 1982 at Site 0300065 were less than or equal to the working criterion for the protection of aquatic life (three samples contained 0.002 mg/L of total copper, four samples were below the detection limit of 0.001 mg/L). Maximum copper values at Site 0300065 have been as high as 0.023 mg/L; however, the median value was below detectable levels(3). There are no known controllable sources discharging copper directly into this drainage basin. The values at Site 0300065 likely reflect natural conditions, therefore no objective for copper has been proposed. It is recommended that more work be done to determine the sources of copper in the lower reaches of the Little Campbell River.

Seasonal variability of iron can be correlated with flow rate and suspended solids concentrations. Total iron values at Site 0300065 were inversely proportional to flow rates and directly proportional to suspended solid concentrations, while upstream, at Site 0300066, total iron values were inversely proportional to suspended solids concentrations and directly proportional to flow rates. All total iron values measured at both sites were at or above the working criteria for drinking water use (0.3 mg/L)(7) for aesthetics, and for the protection of aquatic life (0.3 mg/L to 1.0 mg/L)(72), but less than the criteria for irrigation use (5-20 mg/L)(6). Historical data from Site 0300065(3) indicate that total iron values also exceeded these criteria between 1972 and 1979. There is a need to measure both dissolved and total iron to determine the form present.

The mean total lead value at Site 0300065 from 1972 to 1979 was 0.001 mg/L (maximum lead value 0.004 mg/L(3)). One of seven total lead values (0.011 mg/L), for the period 1979 to 1982 exceeded the working criterion of 0.004 mg/L(84) for the protection of aquatic life, based upon the minimum hardness of 18.3 mg/L. This same sample contained the highest recorded suspended solids (63 mg/L) value, and may have been related to stormwater runoff. Lead values at Site 0300066 were below the detection limit of 0.01 mg/L, which is too high to allow a comparison with the criterion. No objective has been proposed for lead since the one high value appears to be related to high river flow and suspended solids values.

Total manganese values exceeded the drinking water criterion for dissolved manganese of 0.05 mg/L(7) in five of the seven samples taken at both sites (Tables 5 and 6). Levels at Site 0300066 were directly proportional to dissolved and suspended solids concentrations and inversely proportional to flow rates. Values at Site 0300065 were relatively constant over the periods of sampling. There is a need to measure dissolved and total manganese to determine the form present. No objective has been proposed for manganese since high levels appear to reflect background.

2.4.2.2 Metal Values in Sediments

One set of sediment samples collected at four sites (Sites 1, 0300065, 5, and 0300066 - Figure 3a) on the Little Campbell River were analyzed for metals. These data are reported in Table 8, and compared to values for sediments from the Fraser River(21), lakes in British Columbia(22), the Squamish Estuary(23), and from a residential stormwater catchment area in Vancouver(24).

Barium, boron, calcium, chromium, magnesium, molybdenum, selenium, strontium, tellurium, thallium, tin, titanium, and vanadium values for B.C. lakes can be high enough to exceed the values from the Little Campbell River. Sediments from the Fraser River, residential stormwater, and the Squamish Estuary were not analyzed for these metals.

The highest value of copper in sediments from the Little Campbell River (250 µg/g) was reported at Site 0300066. This value exceeded all values recorded elsewhere in B.C. (Table 8). Similarly, the cadmium value (3 µg/g) at this site exceeded values from four sites in the Fraser River (range 0.1 µg/g to 0.3 µg/g). Aluminum, iron, and manganese were relatively high compared to sediments from other areas, except B.C. lakes (Table 8). This is likely related to higher values for these metals in the water column.

The maximum lead (100 µg/g) and zinc (270 µg/g) values in the Little Campbell River were for sediments from Site 0300065. The lead value for this site was exceeded by values found at the residential stormwater monitoring site and sediments from B.C. lakes (Table 8). Since upstream lead values were 24 and 30 µg/g, and stormwater can contain fairly high levels of lead, presumably from automobile emissions, the higher values may be occurring due to stormwater entering the Little Campbell River. The values for zinc at Site 0300065 were only exceeded by values for sediments in B.C. lakes (Table 8).

2.4.3 NUTRIENTS

2.4.3.1 Nutrients in the Water Column

The highest nitrogen and phosphorus values typically occurred at Site 0300066 during periods of high flow and low productivity. The highest total ammonia values at Sites 0300065 and 0300066 were for samples collected in February 1979 and 1981. Ammonia, pH, and temperature values at both sites and associated provincial criteria for maximum and average total ammonia for the protection of aquatic life(69) are in Table 6. The highest recorded total ammonia value at either site was 0.39 mg/L, while the lowest maximum criteria value was 1.54 mg/L and the lowest average criteria value was 0.30 mg/L. These data indicate that acute or chronic ammonia toxicity is unlikely to occur at any time throughout the year in the Little Campbell River.

Although there are no apparent ammonia toxicity problems, not very many data have been collected, and there are nonpoint sources of ammonia in the watershed. Therefore, provisional objectives are proposed for average and maximum total ammonia nitrogen values. These are that values should not exceed the maximum and average values outlined in Tables 29 and 30. The objectives apply to the Little Campbell River and tributaries, except in initial dilution zones of effluents, described in Section 2.4.1. The average value is to be calculated from a minimum of five samples collected in a 30-day period.

The maximum recorded nitrite values were 0.024 mg/L at Site 0300065 and at Site 0300066. These values were less than the provincial water quality criterion for nitrite of 0.06 mg/L as an average value(8) for chloride levels greater than 4 mg/L. Nitrite can be toxic to aquatic life, and can be formed when ammonia is oxidized. The following are proposed as objectives for nitrite to protect aquatic life.

Chloride Concentration (mg/L)	Maximum Nitrite Concentration (mg/L-N)	30-d Average Nitrite Concentration (mg/L-N)
<2	0.06	0.02
2-4	0.12	0.04
4-6	0.18	0.06
6-8	0.24	0.08
8-10	0.30	0.10
>10	0.60	0.20

The objectives apply to the Little Campbell River, Fergus Creek, Sam Hill Creek, Highland Creek, Jacobson Creek, and two unnamed creeks represented in Figure 5, except in initial dilution zones of effluents described in Section 2.4.1. The average value is to be calculated from a minimum of five samples collected over a 30-day period.

Total dissolved phosphorus values were similar at Site 0300066, near the headwaters, and at Site 0300065 near the mouth of the Little Campbell River (Tables 4 and 5). Values for total dissolved phosphorus increased during periods (November to March) of high flow and low productivity at Site 0300065 and, to a lesser extent, at Site 0300066.

Biologically available nitrogen concentrations (sum of nitrate/nitrite plus ammonia) were high during periods of low productivity and high flow, while lower values were associated with periods of high productivity and low flow. Both biologically available nitrogen and total dissolved phosphorus values (Table 7) were high enough to sustain a heavy algal growth provided that such physical factors as light, turbidity, turbulence, substrate, and stream velocity were suitable.

Nitrogen:phosphorus ratios (Table 7) were calculated to determine the nutrient which limits algal growth in the Little Campbell River. At Site 0300066, nitrogen appeared to be the limiting factor ($N:P<5$)in samples collected in September. Phosphorus was the limiting factor ($N:P>15$) for all samples collected at Site 0300065 and in samples collected at Site 0300066 during February, May, and November(29).

The provincial water quality criteria for nutrients and algae in streams limits chlorophyll-*a* levels to 50 mg/m^2 in recreational areas and 100 mg/m^2 for the protection of aquatic life(9). No chlorophyll-*a* data for the Little Campbell River were available. It is recommended that chlorophyll-*a* data be collected on a routine basis to determine if these criteria are met in the Little Campbell River basin. However, to protect recreational use, a provisional objective is proposed. The objective is that chlorophyll-*a* levels in periphyton collected on natural substrate should not exceed 50 mg/m^2. The objective applies along the length of the Little Campbell River, except in the initial dilution zones of effluents, described in Section 2.4.1. It is recognized that this proposed objective is likely not met.

2.4.3.2 Nutrient Values in Sediments

One set of sediment samples from four stations on the Little Campbell River was analyzed for organic carbon, nitrogen, phosphorus, BOD_5, and percentage of total volatile residue (organic content) (Table 8). The location of the sites in Table 8 are shown in Figure 3a. The highest values for organic carbon (23.0 mg/g), nitrogen (2.8 mg/g), BOD_5 (1.97 mg/g), and percentage of total volatile residue (organic content) (11.1%) were recorded at Site 0300066 near the headwaters. Phosphorus values increased slightly from Site 0300065 near the mouth (0.468 mg/g) upstream to Site 0300066 (0.699 mg/g).

Sediment data from the Little Campbell River were compared to the Serpentine and Nicomekl River sediment data in Tables 11(b) and 20, respectively. Kjeldahl nitrogen values from the Little Campbell River were higher than those from the Nicomekl River, but lower than those from the Serpentine River. Total phosphorus values from the Little Campbell River were within the ranges reported for the Serpentine and Nicomekl Rivers. Organic carbon values from the Little Campbell River were similar to those reported for the Nicomekl River.

Sediment data from the Little Campbell River then were compared to data from Sturgeon Bank, adjacent to the Iona sewage treatment facility(21), B.C. lakes(22), and the Squamish Estuary(23). Organic carbon values for the Little Campbell River were lower than those from Cattermole Creek in the Squamish Estuary(23) or some lake sediments(22). Total phosphorus and Kjeldahl nitrogen values for the Little Campbell River were similar to values near the Iona sewage treatment facility, but lower than those from some lake sediments(22)(Table 8). The percentage of organic material in some lake sediments(22) was substantially greater than in sediments from the Little Campbell River (Table 8).

Nutrient values for sediments collected near the headwaters of the Little Campbell River were similar to sediments adjacent to Iona Sewage

Treatment facility. This suggests that nutrients may be sorbing onto sediments near the headwaters.

2.4.4 OXYGEN AND OXYGEN-CONSUMING MATERIALS

The lower reaches of the Little Campbell River are used as a salmonid migratory route between August and November. During this period at Site 0300065, dissolved oxygen values ranged from 8.1 to 14.2 mg/L (mean: 9.8 mg/L), while percent saturation values ranged from 78.7 to 139.2% (mean: 92.1%). All recorded dissolved oxygen values during this period at Site 0300065 were above 8.0 mg/L. Dissolved oxygen values in the upper reaches at Site 0300066 between August and November ranged from 2.3 to 6.5 mg/L (mean: 4.5 mg/L). Percent saturation values at Site 0300066 during this period ranged from 23 to 68.7% (mean: 44.1%). Some fish kills in the area of the Little Campbell River near Site 0300066 have been attributed to low dissolved oxygen levels(40).

Spawning can occur in the river and its tributaries from November to May. Between November and May, dissolved oxygen concentrations ranged from 4.2 to 13.1 mg/L (mean: 8.8 mg/L) at Site 0300066, and from 9.5 to 13.5 mg/L (mean: 11.4 mg/L) at Site 0300065. Criteria developed for fish hatcheries are a minimum 8.0 mg/L dissolved oxygen during the period between egg fertilization and "eyed" egg stage, and concentrations between 8.5 and 12 mg/L (temperature dependent) during the period from "eyed" egg stage to hatch(61). These criteria are not directly applicable to streams because in hatcheries eggs are held in trays in the water column, whereas in streams the eggs are in the gravels and there is a differential of ≈3 mg/L between the water column and the interstitial water in the gravels. A water quality criteria document prepared by the U.S. EPA indicated that no impairment to salmonids occurs at 8.0 mg/L for most life stages or at 11.0 mg/L when embryo larvae are present(83). Slight impairment occurs at levels of 6.0 mg/L and 9.0 mg/L, respectively(83).

At Site 0300066, 7 of 16 measurements, when paired with corresponding temperature data, were less than the criteria which are temperature dependent(61). Since percent saturation values ranged from 45.4 to 103.2% (mean: 70.1%), it is possible in many situations that dissolved oxygen concentrations should be raised to protect aquatic life. At Site 0300065, 14 of 21 samples, when paired with temperature data, met the criteria(61) which vary with temperature. Percent saturation values at Site 0300065 during this period ranged from 79.5 to 112.3% (mean: 97.4%). These data indicate that there is not the same need nor opportunity to improve dissolved oxygen concentration at Site 0300065.

It is apparent that there are periods when there are real concerns with low dissolved oxygen levels in the river. Any proposed objective must recognize this situation, and encourage improvements to be made in the watershed which will be reflected in higher dissolved oxygen concentrations. Therefore, a staged provisional objective is proposed for the minimum dissolved oxygen concentration. Initially, the minimum dissolved oxygen concentration should not be less than 6.0 mg/L in the period from June through October recognizing that there will be a slight impairment to salmonids. Once this minimum is consistently met, the objective for a minimum value should be increased to 8.0 mg/L to provide for no impairment of mature salmonids. This latter objective has been met in the Lower Little Campbell River in the past. In addition, the minimum dissolved oxygen concentration should not be less than 11.0 mg/L when fish larvae and/or alevin are present. These objectives apply to in-situ measurements or discrete samples taken outside the initial dilution zones of effluents. These excluded initial dilution zones in streams are defined as extending up to 100 m downstream from a discharge (and up to 100 m upstream at times of tide reversal), and occupying no more than 50% of the stream width around a discharge point, from the bed of the stream to the surface.

There are no permitted point-source discharges within the Little Campbell drainage basin which impact dissolved oxygen values. Remedial activities would therefore relate to non-point sources which may decrease dissolved oxygen. These can include agricultural discharges through drainage ditches.

2.4.5 BACTERIOLOGICAL QUALITY

Fecal coliform data (n=9) from Site 0300066 met the working criteria for recreational and irrigation use (200-400 MPN/100 mL)(30) on all but one occasion (5400 MPN/100 mL, September 1980), while four of nine samples from Site 0300065 met the criterion. Drinking water or livestock water (confined feeding) would require complete water treatment (coagulation-flocculation, sedimentation, filtration and disinfection) prior to use(50); however, the B.C. Ministry of Health does not approve of the use of these waters as a drinking water supply.

It is proposed that provisional objectives be established for the Little Campbell River and its tributaries. The proposed objectives are that the geometric mean fecal coliform value should be ≤200 MPN/100 mL from April through October. The 90th percentile value should be ≤400 MPN/100 mL from April through October. These objectives apply to samples taken anywhere in the Little Campbell River basin outside the initial dilution zones of effluents, described in Section 2.4.1. Mean values and 90th percentile values should be based upon at least five samples collected in a 30-day period. Drinking water licence holders should be advised that, at present, complete water treatment may be necessary for Little Campbell River water prior to using for drinking or livestock watering purposes. Further monitoring of fecal coliforms and fecal streptococci should be conducted to determine present levels and sources of fecal contamination within the basin.

2.4.6 SOLIDS

Suspended solids data (ten samples collected from 1979 to 1983) from Site 0300066 ranged from 2 mg/L to 22 mg/L and from 4 mg/L to 63 mg/L at Site 0300065. No seasonal trends were observed at either site over the sampling period. Values at Site 0300066 are such as to provide an excellent level of protection (<25 mg/L) to fisheries(13), while those at Site 0300065 would provide a good to moderate level of protection (25-80 mg/L)(13).

The provincial water quality criteria for particulate matter are that induced non-filterable residue should not exceed 10 mg/L when background non-filterable residue is ≤100 mg/L and should not be more than 10% of background when background is >100 mg/L(14). An objective is therefore proposed that induced non-filterable residue should not exceed 10 mg/L if background levels are ≤100 mg/L and should not be more than 10% of background if background levels are >100 mg/L in the Little Campbell River or its tributaries. This objective applies to discrete samples taken outside the initial dilution zones of effluents as described in Section 2.4.1.

In addition, to protect salmonid spawning areas, there should be no significant (95% confidence level) induced benthic sedimentation on the basis of accumulation by weight for particles <3 mm.

The provincial criteria(14) for turbidity to protect aquatic life and for drinking waters with some form of treatment is that induced turbidity should not exceed 5 NTU when background is less than 50 NTU. When background is greater than 50 NTU, the induced turbidity values should not be more than 10% of background. For irrigation, the criterion is that induced turbidity should not exceed 10 NTU when background is less than 50 NTU, and should not be more than 20% of background when background turbidity is greater than 50 NTU. An objective is therefore proposed that induced turbidity should not exceed 5 NTU if background levels are ≤50 NTU and should not be more than 10% of background if background levels are >50 NTU in the Little Campbell River or its tributaries. The objectives apply to discrete samples taken outside the initial dilution zones of effluents as described in Section 2.4.1.

Dissolved solids ranged from 76 mg/L to 142 mg/L at Site 0300065 and from 66 mg/L to 108 mg/L at Site 0300066. Dissolved solids levels were substantially lower than the most sensitive criterion of 500 mg/L for drinking water(52) and irrigation(4).

2.5 RECOMMENDED MONITORING

The quantity of data (maximum number of ten samples analyzed in an eight-year period) and the seasonal component of proposed water quality objectives predicate the need for an intensive monitoring program at Sites 0300065 and 0300066. Water samples and field measurements should be collected five times in a 30-day period between June and September, and five times in a 30-day period between November and January. Field measurements should be made for dissolved oxygen, pH, specific conductivity, and temperature. Laboratory measurements, as a minimum, should be made for ammonia, nitrate, nitrite, periphyton chlorophyll-a, dissolved orthophosphorus, total phosphorus, fecal coliforms, suspended solids, dissolved solids, turbidity, and dissolved and total copper, iron, manganese, and lead. As well, further monitoring of fecal coliforms and fecal streptococci should be conducted to determine present levels and sources of contamination within the basin.

Border Sand and Gravel Ltd. (PE 4256) has intermittently discharged to Ellen Creek and Jacobson Creek, while Hazelmere Riverside Campground, owing to its proximity to Little Campbell River, may contribute to the elevated fecal coliform values in the river. Monitoring programs for these two operations have been outlined in sections 2.3.2.2. and 2.3.3.2.

To assess the impact of upland urban development in the Little Campbell drainage basin on water quality, a one-year monitoring program is recommended. This study should identify the number of stormwater sewers from White Rock and the quantity and quality of discharge into the drainage basin. Field and laboratory measurements should be taken at at least one stormwater outfall, a site on Fergus Creek and sites on the Little Campbell river upstream and downstream from Fergus Creek. Field measurements should include flow rates, dissolved oxygen, pH, specific conductivity, and temperature. Laboratory analyses should, as a minimum, be made for ammonia, nitrate, nitrite, total dissolved phosphorus, fecal coliforms, fecal streptococci, dissolved and suspended solids, total alkalinity, hardness, total and dissolved copper, total and dissolved lead, and total and dissolved zinc. Swain(24) has recommended that rainfall and dustfall monitoring be conducted in conjunction with this type of program. Ambient air (dustfall) sampling should be conducted monthly while water and rainfall sampling should be conducted on a precipitation event basis.

Actual monitoring undertaken will depend upon available resources and regional priorities.

2.6 CONCLUSIONS

The Little Campbell River is of good quality in terms of low metal and ammonia nitrogen values. It has moderate to low buffering capacity to acidic discharges and is usually classified as soft. To prevent the fouling of plumbing systems and for the protection of sensitive aquatic life a provisional water quality objective has been proposed for pH. Nitrate nitrogen, ammonia-nitrogen, and phosphorus concentrations decreased during periods of low flow and high temperature. Low flows and high temperatures also contributed to low dissolved oxygen values.

Bacteriological quality, in terms of fecal coliform concentrations, was generally poor throughout the system. An objective has therefore been proposed related to fecal coliform values during the irrigation and recreation seasons. Dissolved oxygen values were low with some seasonal variability near the headwaters. Provisional objectives have been proposed for dissolved oxygen.

3. SERPENTINE RIVER

This drainage basin contains three tributaries. These are Latimer Creek, Hyland Creek, and Mahood (Bear) Creek (Figures 3 and 5). Latimer Creek is 6 km long, has a drainage area of 14.5 km^2 within the Clayton upland, and extends eastward to 2 km past the farming community of Port Kells. The largest and most industrialized drainage area is Mahood (Bear) Creek (38 km^2) within the Newton upland. This upland also contains the 8.8 km long Hyland Creek (12.6 km^2) which extends west from the Serpentine River to Newton.

The surficial material in these tributaries is comprised of stony marine clays, till and till-like mixtures situated at or near the surface. The relatively impervious nature of these soils results in much of the precipitation entering the system as direct runoff. The Serpentine drainage basin (132 km^2) is comprised of an upland component (Clayton and Newton Uplands) and a lowland component (22 km of ditches and dyked channels through predominantly agricultural land).

In the Serpentine fen area, there is a triangular drainage pattern (near Site 1100049). The one straight stretch is a man-made ditch.

3.1 HYDROLOGY

The locations of flow gauge stations within the Serpentine River drainage basin are on Figure 3. Sites 08MH018 and 08MH020 were operated on Mahood (Bear) Creek from 1926 to 1928, and from 1959 to 1984, while Site 08MH060 operated intermittently from 1961 to 1966 on the Serpentine River near Port Kells (upstream from Mahood Creek). All three stations are located in the headwaters of the Serpentine basin. Two-year and ten-year, seven-day average low flow rates were calculated to be 0.0145 and 0.0025 m^3/s at Site 08MH018 and 0.073 and 0.0175 m^3/s at Site 08MH020. Based on one complete year of data and two partial years, the two-year return flow on the Serpentine River would be 0.057 m^3/s at Site 08MH060.

Periods of low flow were typically between June and September while maximum flows typically occurred between November and January. Maximum flows on Mahood Creek were 25 m^3/s at 08MH018 and 28.3 m^3/s at 08MH020. On the Serpentine River, the maximum flow at Site 08MH060 was 5.92 m^3/s recorded in 1965 when infrequent measurements were taken.

Ten flow measurements taken at Site C on Latimer Creek (Figure 3) in the summer of 1977 ranged from 0.01 to 0.06 m^3/s. A large percentage of this flow was attributed to groundwater contributions(28). On Hyland Creek, seven flow measurements were taken at a site three kilometres upstream from the Serpentine River, between June and September 1977. Flows ranged from 0.06 to 0.30 m^3/s (mean: 0.09 m^3/s; median: 0.06 m^3/s).

3.2 WATER USES

Irrigation is the major use of water withdrawn from this drainage basin (Figure 3). Licenced withdrawals from the lowland portion of the Serpentine River account for 80% (1 674 dam^3) of the total annual volume used (2 085 dam^3) for irrigation. Two licences permit 1.14 m^3/d of water to be withdrawn for stock watering, one licence permits 4.65 m^3/d of water to be withdrawn for drinking water, and 1 233 dam^3 of water is used to supplement the waterfowl refuge operated by the Wildlife Branch. Two licences permit 176 dam^3 to be withdrawn for industrial use (11.36 m^3/d by a greenhouse-operation and 171 dam^3 by a cranberry farm).

Hyland Creek is licenced for water withdrawals of 98.7 dam^3 for irrigation use, and 45.5 m^3/d for industrial use (brickyard). Similar uses are made of waters from Latimer Creek: 23.4 dam^3 being used for irrigation, 2.3 m^3/d for stock watering, and 431.7 dam^3 for industrial use (forest nursery) from Latimer Pond. In Mahood (Bear) Creek, 75.9 dam^3 of water is used for irrigation, and 6.2 dam^3 for industrial use (golf course).

Steelhead and cutthroat trout utilize the Serpentine River system. Locations of spawning and rearing areas within the Serpentine River basin are on Figure 5. Coho salmon spawn in the mainstem of the Serpentine River near the headwaters upstream from Port Kells, as well as in the headwaters of Hyland Creek, in Mahood (Bear) Creek, and in Latimer Creek.

The coho salmon population has fluctuated considerably over the last three decades (Table 9). The lowest recorded values for individuals spawning (75) occurred in the Serpentine River in 1969. The highest values occurred in 1971 and 1976, when 3 500 individuals spawned. Generally, values in the 1950's ranged from 400 to 1 500 (mean 1 165). This decreased through the 1960's (range 75 to 750; mean 363). In the 1970's the numbers of coho spawning in the Serpentine River increased to a level higher than those found in the two previous decades (range 750 to 3 500; mean 2 125). Numbers in the early 1980's decreased to a mean of 638 (range: 350 to 1100). Spawning of coho salmon begins in late October, reaches its peak in mid-November, and is finished by late December.

Recreation is limited to non-contact activities (e.g., boating), usually from the mouth of the Serpentine River upstream to the floodgates, although a minimal amount occurs upstream from the floodgates.

3.3 WASTE DISCHARGES

The location of operations issued permits to discharge effluents within the Serpentine drainage basin pursuant to the Waste Management Act are represented by their permit number in Figure 3. No permitted effluent is discharged directly to the Serpentine River; however, cooling water, stormwater, and effluent from an iron foundry are discharged to Mahood (Bear) Creek. Treated stormwater runoff from a concrete ready-mix operation is discharged to Hyland Creek. The remaining operations discharge effluent to soil disposal systems. Diffuse sources of waste include agriculture and urban stormwater.

3.3.1 SMITH TRAILER PARK LTD. LANGLEY (PE 209)

This operation is located 61 m north of Latimer Creek, about three km south from Barnston Island (Fraser River) and more than five km to the east from the Serpentine River. It is allowed under permit PE 209, issued in 1967, to discharge an average of 43.19 m^3/d of domestic sewage treated in a septic tank to two tile fields, each containing 610 m of tile. The system is designed to service 50 independent and 20 dependent trailer spaces (to be completed in three stages). The area has a low groundwater level and is characterized by sandy soil resulting in high percolation rates. The location of the tile field should result in little impact on water quality of the Serpentine River, although some impact may occur on Latimer Creek.

3.3.2 FERRO ENAMELS, SURREY (PE 2208)

Ferro Enamels is a paint manufacturing plant located near the headwaters of Mahood (Bear) Creek. Permit PE 2208, issued in 1973, allows the discharge of cooling water to Mahood (Bear) Creek. The average permitted discharge is 1.64 m^3/d, while the maximum is 2.18 m^3/d. There is a minimum dilution ratio of about 575:1 at the maximum permitted discharge rate and at the two-year, seven-day low flow. Since the permitted discharge rate is so small, it is well diluted whenever there is any flow in the creek. The maximum permitted temperature in the effluent is 27°C.

One analysis of the cooling water in 1978 indicated that it contained an oil and grease value of 2 mg/L, and a suspended solids value of 2.6 mg/L.

The small quantity of this discharge would likely have a negligible impact on the water quality of Mahood (Bear) Creek.

3.3.3 B.C. HYDRO AND POWER AUTHORITY, SURREY (PE 6026)

B.C. Hydro operates a repair shop and transformer storage area downstream from Ferro Enamels on Mahood (Bear) Creek. This permit allows for a maximum daily stormwater discharge of 1 250 m^3 containing 5 mg/L of oil and grease from this facility. Discharge is via a ditch to Mahood (Bear) Creek at 128th Street in Surrey. The electrical shop carries out routine maintenance and overhauling of powerline transformers and capacitors. Stormwater runoff which may contain oil, is treated by two gravity oil separators with a combined capacity of 1 154 m³. Such a system under average precipitation conditions will provide a minimum of 24 hours retention to remove the oil.

Twelve samples were collected between 1981 and 1984 at the separator. The dilution ratios for the effluent in Mahood Creek ranged from 1.7:1 to 37:1, based on effluent flows from 34 m³/d to 729 m³/d and two-year low flows at station 08MH018. However, the flow in Mahood Creek at 08MH018 is probably twice that near the waste discharges. Thus the dilution ratios are likely closer to 0.8:1 and 18:1, respectively.

Eight samples taken between 1982 and 1984 were analyzed for PCBs. These samples were collected from the separator, at two sites within the stormwater system, and in the open ditch near the confluence with Mahood (Bear) Creek. PCB values from four samples collected at the separator ranged from below detectable levels (0.0004 mg/L) to 0.012 mg/L with a mean of 0.0036 mg/L. One sample was collected from the ditch site in 1981 with a PCB value of 0.006 mg/L when the effluent flow rate was 552 m³/d.

Using the PCB concentration of 0.006 mg/L found in the ditch and a minimum dilution ratio of 1.7:1, PCBs in Mahood Creek are calculated to be increased by 0.0035 mg/L due to this discharge, assuming complete mixing. This would exceed working water quality criteria for drinking water (3 µg/L) (75) and the protection of aquatic life (0.001 µg/L)(76). It is unlikely that low flows would coincide with precipitation events, and thus the drinking water criterion was probably not exceeded. However, dilutions of <400 to 12 000 would be needed to meet the aquatic life criterion which was probably exceeded. Provisional water quality objectives for PCBs are proposed in Section 3.4.7.

Further ambient monitoring for PCBs is recommended in Mahood Creek upstream from this discharge, in the ditch immediately downstream from this discharge, and 100 m downstream from the point of discharge. Samples of water, fish, and sediments should be collected to determine if objectives are also required for sediments and fish. The frequency should be based upon precipitation events and analytical results.

3.3.4 ASSOCIATED FOUNDRY LTD. SURREY (PE 1529)

This operation, located near the headwaters of Mahood (Bear) Creek, was described earlier by Swain(17). Scrap iron is melted at this facility to produce plumbing pipe. Wastewater treatment consists of an oil separator and a series of catch basins. The effluent is discharged to Mahood (Bear) Creek.

Swain reported that the permit levels, equivalent to level 'C' pollution control objectives for metal finishing plants and industries discharging heavy metals, were not met for flow rate, pH values, and suspended solids(17). Suspended solids were in compliance approximately 50 percent of the time. High values for oil and grease were also reported. Data in Table 10, collected between 1978 and 1982, indicate that oil and grease, pH, and suspended solids still exceeded permitted levels in more than 50 percent of the samples taken. The flow rate met levels allowed in permit PE 1529 (pH range 6.5-8.5, flow rate average 90 m^3/d). The minimum dilution ratio available for the effluent, using the two-year and ten-year, seven-day average low flow rates for Site 08MH018, would be approximately 14:1 and 2.4:1, respectively or 7:1 and 1.2:1 if appropriate flows at the point of discharge are considered.

This operation has the potential to increase temperature, oil and grease, suspended solids, and iron values to some degree in the creek. The estimated minimum dilution is not likely to provide an adequate safety factor to prevent considerable impacts being evident in the creek.

3.3.5 RELIANCE FOUNDRY CO. LTD. SURREY (PE 2549; PR 2550)

The foundry is located at the headwaters of Mahood (Bear) Creek. It was issued a permit (PE 2549) allowing the discharge of 115 m^3/d of once-through cooling water at a temperature of 24° C. The discharge is to a ditch which carries the cooling water southeast for 200 m then into another ditch flowing northwest to Mahood (Bear) Creek. The minimum dilution available, assuming the maximum daily discharge rate and the ten-year and two-year, seven-day low flows for Site 08MH018, would be approximately 1.9:1 and 10.9:1, respectively or about 0.9:1 and 5:1 if approximate flows at the point of discharge are considered. Swain reported that effluent data indicated that the permit limits were being met(17). Samples collected upstream and downstream from the foundry in February 1980 showed that the pH of the creek decreased from 6.8 to 6.5, while the specific conductivity increased from 66 to 193 uS/cm. It is recommended that more data related to the impact of this discharge on the creek be collected.

The company also operates an industrial landfill adjacent to the foundry. Permit PR 2550, issued in 1973, allows the discharge of an average 0.03 m^3/d (averaged over a five-day week) of refuse. The refuse disposed of in the landfill consists of moulding sand (85%), sand slag (10%), and broken refractory (10%).

The landfill is located 3 m from a drainage ditch. The water table has been recorded approximately 0.3 m below the bottom of the site and the typical soil profile is Newton stoney clay (to a depth of 3 m). The service life of this landfill was thought to be five years (in 1973). Owing to the nature of the refuse being discharged, no covering is required. As well, it is expected that any impact on the water quality of Mahood (Bear) Creek would be minimal.

Periodic inspections of the site by the Regional Waste Management Branch with bi-annual monitoring of the nearby ditch for iron content was proposed for this permit. No data have been recorded on the data storage system operated by the Ministry of Environment and Parks.

3.3.6 GOODBRAND CONSTRUCTION LTD. SURREY (PE 6050)

This ready-mix concrete truck washing operation is located on Hyland Creek approximately 1 km west from the Serpentine River. The operation was issued permit PE 6050 in 1982, allowing the discharge of 29 m^3/d of cement washwater into settling/recycle ponds (127 m^3 capacity).

A maximum of 240 m^3/d overflow from a settling pond (24-hour retention) handling yard drainage and some truck washdown water is permitted to be discharged to Hyland Creek. The minimum dilution available for such discharges is not known. No effluent data were available for this site. It is not known if the discharged wastewater has a high pH when it is discharged. It is recommended that samples of the effluent, as well as creek samples both upstream and downstream from where the effluent enters the Creek, be taken and analyzed for pH, dissolved and suspended solids, turbidity, and hydrocarbons.

3.3.7 ALPULKA INVESTMENTS LTD. (PE 5276)

This operation is located just east from the Surrey Centre. The company was issued permit PE 5276 in 1980 for the discharge of treated domestic sewage at a maximum rate of 14 m^3/d from a proposed shopping center in the Township of Langley to 280 m of tile field. The permit also requires the effluent to have maximum concentrations of 45 mg/L BOD_5 and 60 mg/L suspended solids.

The sewage is treated in a package aeration secondary-treatment plant. A sludge holding tank (40 m^3) with aeration capacity of 70 m^3/d and a hydraulic loading not to exceed 16 m^3/d is incorporated to store effluent in the case of a system failure.

The small quantitites of sewage involved, the high level of treatment provided, and the fact that the treated sewage is discharged to a soil adsorption system over two km from the Serpentine River, would indicate that this operation should have no impact on the water quality of the Serpentine River.

3.3.8 OSWALD SEILER, SURREY (PR 5360)

This landfill is located just west from the Surrey Centre. It was issued permit PR 5360 in 1979, allowing the deposition of 523.9 m^3 to the site over a one-year period. The total depth of the refuse was to be 1 m of hog fuel covered by 1 m of sand, and then the entire area was to be paved. Drainage ditches are located on three sides of the site carrying runoff water to the Serpentine River (0.75 km away). The depth to the groundwater table was estimated to be approximately 1 m.

The life of the landfill was projected to be until October 1979. In 1984, 1 acre of the 3-acre landfill was asphalted, the remaining portion was covered with 0.6 m of impervious construction material and a layer of sand and gravel. No impact on the Serpentine River is anticipated from this operation.

3.3.9 DIFFUSE SOURCES

The Serpentine drainage basin has 7 441 ha serviced by municipal sewers and 5 746 ha of unsewered agricultural area. Within this drainage basin there was a 1981 population(79) of 8 341 which resided in Cloverdale, 16 835 resided between Mahood (Bear) Creek and the Serpentine River, and 64 770 resided in the Newton Uplands. This latter area impacts the upper reaches of the Serpentine River and Mahood (Bear) Creek with stormwater runoff and is predicted to approximately double in population by 1996 (124 200)(80). Therefore, stormwater management issues should be addressed to prevent substantial increases in chemical loadings and to minimize scouring of salmonid rearing and spawning channels in the upper reaches of the Serpentine River and Mahood (Bear) Creek.

Three feedlot operations, registered by the Beef Assurance Program as outlined in Section 2.3.1.2, are situated within the Serpentine drainage basin. The largest of these is located in the Newton Uplands near Mahood (Bear) Creek (maximum value of 6000 head recorded in 1982, mean five-year value of 842 head)(Figure 3). Facilities near the headwaters (26 cows, 26 calves, and 2 yearlings) of the Serpentine River, on the floodplain near Cloverdale (75 yearlings, 75 finishing cattle), and near the mouth of the river (57 cows, 58 calves, 6 finishing cattle) are more representative of the size of feedlots operating in the Lower Mainland.

Phosphorus and nitrogen loadings to the Serpentine River, assuming 100% transmission, were estimated to be about 28 000 kg and 393 900 kg, respectively. The impact of the release of these nutrients would depend upon the period of their release, and the flow in the river. Typical flow rates for the Serpentine River are not available. However, if the maximum recorded flows for Sites 08MH020 and 08MH060 were added, a flow in the Serpentine of about 35 m^3/s would result. These loadings do not include losses from other agricultural activities such as the application of chemical fertilizers.

Using this flow, the following increases could be possible in the river, based upon the following release periods and assuming that the nutrients accumulate during a one-year period.

Period of Release	Potential Increase (mg/L)	
	Phosphorus	Nitrogen
4 weeks	27.8	32.6
2 weeks	55.5	65.1
1 week	111	130

Obviously, such large increases do not occur due to the transmission coefficient being less than 100%, accumulations not occurring for as long as one year, and larger flows being available for dilution. Actual riverine conditions are discussed in Section 3.4.3.

3.4 WATER QUALITY AND PROPOSED PROVISIONAL WATER QUALITY OBJECTIVES

Water quality data have been collected at ten sites along the Serpentine River, as well as on Hyland, Mahood (Bear), and Latimer Creeks from 1974 to 1982. These data have been reported by Arber(28), Bourque and Hebert(25), and Hirst et al.(33) for the period 1974 to 1977. This report includes these data for seasonal and long-term trends in water quality and sediment chemistry data, and adds data collected between 1979 and 1982. The data are in Tables 11a and 11b, 12, 13, 14, and 15. The locations of the sites are shown on Figure 3.

Proposed designated water uses for the Serpentine River, and Hyland, Latimer, and Mahood (Bear) Creeks are the protection of aquatic life, wildlife, livestock, and irrigation.

3.4.1 pH AND BUFFERING CAPACITY

Total alkalinity on the Serpentine River (Table 11a) ranged from <0.5 to 113 mg/L at Site 1100049, with mean values ranging from 4.8 at Site 1100037 to 65.8 mg/L at Site 1100034. These data indicate that the Serpentine River has a moderate to low buffering capacity to acidic discharges. Generally, low alkalinity values occurred from January to March, a period with high precipitation. Under these conditions, streamflows are dominated by surface runoff which has had little contact with the surficial geological materials that impart buffering agents to the water.

In Mahood Creek (Table 13), alkalinity values ranged from 16.1 mg/L to 68.1 mg/L at Site 1100056. Mahood Creek, with a mean alkalinity value of 43.3 mg/L, had more buffering than the Serpentine River. Alkalinity data were not collected for either Hyland or Latimer Creeks (Tables 12 and 14); however, similar buffering capacities to Mahood Creek would be anticipated based upon data for pH.

The highest values for pH in the Serpentine River were recorded at Site 1100037 near the headwaters (range: 6.7-9.3; median 7.5), while the lowest value was recorded at Site 1100049 at the Serpentine fen (range: 3.8-7.7; median 5.1). The pH range for the protection of aquatic life is 6.5 to 9.0(31), while for drinking water it is 6.5 to 8.5(7). Values less than 6.5 were found in four of sixty-six samples at Site 1100034, five of forty-one samples at Site 1100035, four of sixty-one samples at Site 0300057, nineteen of thirty-two samples from Site 1100049, three of fifty-eight samples from Site 0300059, and greater than 8.5 for five of forty-two samples from Site 1100037, one of 66 samples at Site 1100034, and two of sixty-one samples at Site 0300057.

In Mahood Creek, the minimum pH was 6.8 at Site 0300056, while the maximum was 8.1 at Site 1100056 (Table 13). Values in Hyland Creek were from 7.4 to 8.0 (Table 12) and from 6.7 to 8.1 in Latimer Creek (Table 14). No samples collected on any of the creeks were outside the working criteria pH ranges.

It is recognized that at higher pH values, ammonia toxicity increases. However, high (and low) pH values exist naturally in the Serpentine River. Such is not the case in Mahood, Hyland, or Latimer Creeks. To protect sensitive aquatic life, a provisional objective is proposed for Mahood (Bear) Creek, Hyland Creek, Latimer Creek and the Serpentine River. The pH should be in the range 6.5 to 8.5. If values upstream are greater than 8.5, then the change in pH going from upstream to downstream from a discharge or series of discharges should not exceed 0.2. The objectives are applicable along the lengths of these creeks and the river except in initial dilution zones of effluents, described in Section 2.4.1.

3.4.2 HARDNESS AND METALS

Values for total hardness at Sites 1100036, 0300059, and 1100037 in the Serpentine River above the confluence of Mahood Creek did not appear to be affected by salt water intrusions. Mean values were 45.4, 51.8, and 36.9 mg/L, respectively (Table 11a). In Mahood Creek, mean values were

45.4 mg/L at Site 0300056 and 48.9 mg/L at Site 1100056 (Table 13). These data indicate that the water is soft, having a hardness value less than 75 mg/L of $CaCO_3$. No data for hardness were available for Hyland or Latimer Creeks.

Hardness values of Site 1100034, 3 km upstream from the mouth of the Serpentine River, were as high as 4 380 mg/L. These values reflect the presence of salt water (specific conductivity of 38 700 µS/cm).

3.4.2.1 Metal Values in the Water Column

Values for total aluminum were collected at Site 0300057 and at Site 0300059 on the Serpentine River (Table 11a) and at Site 0300056 on Mahood Creek (Table 13). The average values at all sites exceeded the criterion of 0.1 mg/L for the protection of aquatic life(6). However, these concentrations appear to be high background rather than the result of anthropogenic activities.

Average total copper values recorded at most sites exceeded the average water quality criterion of 0.002 mg/L for the protection of sensitive aquatic life at hardness below 50 mg/L(66). The maximum recorded copper values seemed to increase in the Serpentine River going downstream, from a maximum recorded value of 0.007 mg/L at Site 1100037 near the headwaters, to a maximum value of 0.03 mg/L at Site 1100034 near the river mouth (Table 11a), although the maximum value at Site 1100035 was 0.05 mg/L. A maximum value of 0.02 mg/L was recorded at Site 0300056 in Mahood Creek (Table 13). One sample in each of Latimer (Table 14) and Hyland Creeks (Table 12) had 0.002 mg/L. The high values in the Serpentine River and Mahood Creek are presumably natural background.

Total lead values throughout the Serpentine River ranged from <0.001 mg/L at several sites to 0.044 mg/L at Site 1100037 (Table 11a). This maximum is substantially higher than found elsewhere in the drainage basin. Mean values at several sites equalled or exceeded the criterion for the protection of sensitive aquatic life (0.003 mg/L) for a minimum recorded hardness of 9.2 mg/L(84). Seven of 22 samples at Site 1100037 exceeded this criterion. A lead value of 0.054 mg/L was recorded at Site 1100056 in Mahood Creek (Table 13), while a value of 0.006 mg/L was found in Hyland Creek (Table 12), and a value of 0.003 mg/L in Latimer Creek (Table 14). These high lead values may originate from stormwater runoff; however, more work is required to confirm this.

The maximum total zinc value collected at Site 1100049 (0.24 mg/L) on the Serpentine Fen was higher than those from any other location within this drainage basin. The maximum zinc value in Mahood Creek was 0.12 mg/L at Site 1100056 (Table 13), 0.005 mg/L in Hyland Creek (Table 12), and <0.005 mg/L in Latimer Creek (Table 14). The mean concentration at the remaining sites (except Site 1100049) were lower than the most sensitive criterion level (0.05 mg/L) for the protection of aquatic life(6). One value exceeded the criterion level at Sites 1100034, 1100035, 1100037, 1100056, and 0300057, while it was exceeded in seven values collected at Site 1100049. Seasonal variability was more pronounced at Site 1100037, in the uplands, where total zinc concentrations increased between October and February. Stormwater runoff may be a contributing factor to higher zinc values during this period(24).

Total iron values collected from most locations in Latimer, Mahood, and Hyland Creeks and in the Serpentine River exceeded the working criteria for drinking water (0.3 mg/L)(7), and for the protection of aquatic life (0.3 mg/L to 1.0 mg/L)(72). The criterion of 5.0 mg/L(76) for continuous irrigation on all soils was exceeded in some samples at Sites 1100049, 1100035, and 0300059 on the Serpentine River and at both sites on Mahood Creek. These high iron values are thought to be naturally occurring. The drinking water criterion of 0.3 mg/L(7) is related to aesthetics, not health concerns.

All total manganese values collected at Site 0300057 in the Serpentive River exceeded the working criterion for drinking water (0.05 mg/L)(7). The working criteria for the protection of aquatic life are 0.10 to 1.0 mg/L(71). The upper criterion was not exceeded in the Serpentine

River or Mahood Creek, although the lower criterion was. No data were collected in Hyland or Latimer Creeks. The drinking water criterion is related to aesthetics, not health.

More data are required for metals along the length of Mahood Creek to determine if the discharges from the two foundries are significantly affecting water quality.

3.4.2.2 Metal Values in Sediments

Metal values in sediments were examined at three sites in 1979 and three sites in 1982 (Table 11b). Sites 0300057 and 1100034 were approximately at the same location, near the mouth of the Serpentine River. Sites 0300059 and 1100036, upstream from the confluence of Mahood (Bear) Creek, were also close together (Figure 3).

Data for eight constituents from the six sites were compared to data from the Main Arm and North Arm of the Fraser River downstream from Pattullo Bridge(21), sediment cores collected from lakes in B.C.(22), and sediments accumulated in urban residential stormwater(24) (Table 11(c)).

Values for copper, iron, lead, manganese, nickel, and zinc in sediments from the Serpentine River were generally of the same order of magnitude or higher than values in sediments from the Main Arm of the Fraser River; cadmium values were lower in the Serpentine River (Table 11(c)).

Metal values in Serpentine River sediments were within the range of values in samples from B.C. lakes(22); cadmium, copper, cobalt, iron, and lead values in the Serpentine River were within the lower part of the range for B.C. lakes. Lead and zinc values were higher in stormwater sediments(24) than in sediments from the Serpentine River, while iron values from the river were higher than those from the stormwater. Manganese, copper and cobalt values from the Serpentine River were within the range of values from stormwater samples.

3.4.3 NUTRIENTS

3.4.3.1 Nutrient Values in the Water Column

Maximum total ammonia nitrogen values throughout the Serpentine River ranged from 0.007 mg/L at Site 1100032 to 0.735 mg/L at Site 1100035. Criteria for the protection of aquatic life are in Table 29 for maximum values and Table 30 for average values. A comparison of actual high total ammonia values with their corresponding pH and temperature values indicated that the criteria for maximum and average total ammonia were met.

The maximum total ammonia nitrogen value in Mahood Creek was 0.38 mg/L at Site 0300056 (Table 13), at a pH of 6.5 and a temperature estimated at 5.0°C. The maximum ammonia level on Hyland Creek was 0.058 mg/L (Table 12). In Latimer Creek, the maximum value was 0.64 mg/L (Table 14) at a pH of 7.7 and a temperature of 18.2°C. None of these concentrations are of concern with respect to ammonia toxicity.

A concern exists for ammonia generated from animal wastes. Therefore, provisional water quality objectives are proposed for the total ammonia nitrogen concentration in the Serpentine River, Mahood Creek, Latimer Creek, and Hyland Creek. Total and average values should not exceed values listed in Tables 29 and 30. The objectives apply in all areas, except initial dilution zones of effluents described in Section 2.4.1. The average value is to be calculated from a minimum of five samples collected in a 30-day period.

Nitrite nitrogen values were as high as 0.246 mg/L at Site 0300057 in the Serpentine River (Table 11a), 0.029 mg/L at Site 0300056 in Mahood Creek (Table 13), 0.011 mg/L in Hyland Creek (Table 12), and 0.049 mg/L in Latimer Creek (Table 14). At chloride concentrations less than 2 mg/L, the B.C. criteria for nitrite are 0.02 mg/L as a 30-day average value and 0.06 mg/L as a maximum value(69). Thus the assumed criteria for maximum values are met in the three tributary creeks. The minimum chloride concentration at Site 0300057 in the Serpentine River was 10.8 mg/L (Table 11a) indicating saltwater intrusion. The corresponding B.C. criteria are a maximum concentration of 0.6 mg/L and a 30-day average value of 0.2 mg/L. Thus nitrite levels is the watershed are below criteria to protect aquatic life.

Since this watershed is used by salmonids and because nitrite can be formed when ammonia is oxidized, provisional objectives are proposed for nitrite nitrogen in the Serpentine River, Mahood Creek, Latimer Creek, and Hyland Creek, as follows:

Chloride Concentration (mg/L)	Maximum Nitrite-N (mg/L) Concentration	30-day Average Nitrite-N (mg/L) Concentration
<2	0.06	0.02
2-4	0.12	0.04
4-6	0.18	0.06
6-8	0.24	0.08
8-10	0.30	0.10
>10	0.60	0.20

These objectives apply in all areas except the initial dilution zones of effluents, described in Section 2.4.1. The average value is to be calculated from a minimum of five samples collected in a 30-day period.

The highest total phosphorus values in the Serpentine River were 1.29 mg/L at Site 1100033 and 1.56 mg/L at Site 1100035 (Table 11a), both in June 1975. Values from Mahood Creek were as high as 0.273 mg/L (Table 13). The maximum value in Hyland Creek was 0.071 mg/L (Table 12), while in Latimer Creek it was 0.089 mg/L (Table 14). The maximum dissolved orthophosphorus was 1.01 mg/L at Site 1100035 (Table 11a) in the Serpentine River, 0.36 mg/L at Site 1100056 (Table 13) in Mahood Creek, 0.034 mg/L in Hyland Creek (Table 12), and 0.167 mg/L in Latimer Creek (Table 14).

These quantities of phosphorus are sufficient to cause excessive algal production, assuming phosphorus is the limiting nutrient and other factors which would have a bearing on algal production such as availability of substrate, light availability, and river velocity are not limiting.

The water quality criteria for nutrients and algae in streams limits the periphyton chlorophyll-a levels to 100 mg/m^2 for protection of aquatic life(9). Chlorophyll-a data were not available for the Serpentine River watershed. Since phosphorus and nitrogen can enter the watershed from agricultural practices, a provisional water quality objective of 100 mg/m^2 chlorophyll-a is proposed, applicable to naturally growing periphytic algae. The objective is to be evaluated from the average of at least five replicates. The objective, in the absence of monitoring data, will have to be a long-term objective. It applies to all parts of the Serpentine River, Mahood Creek, Latimer Creek, and Hyland Creek, except in the initial dilution zones of effluents, described in Section 2.4.1.

3.4.3.2 Nutrient Values in Sediments

Nutrient values in sediments were examined at three sites in 1979 and three sites in 1982. A description of the sites is in Section 3.4.2.2.

Stancil(21) reported data (mean values for transects) for samples collected by B.C. Research (Figures 11a and 12a in reference 21) for total phosphorus and Kjeldahl nitrogen adjacent to the Iona STP outfall. A comparison between these two locales is shown below.

Constituent	Serpentine River	Adjacent to Iona STP(21)
Total Phosphorus (mg/L)	0.303 - 1.49	0.588 - 0.910
Kjeldahl Nitrogen (mg/L)	0.31 - 5.6	0.221 - 0.728

This indicates that the sediments in the Serpentine River generally have more phosphorus and nitrogen than sediments adjacent to the Iona STP outfall, an area considered to be heavily polluted by municipal effluent. Elevated phosphorus and nitrogen values may be attributed to the agricultural practices conducted within this drainage basin.

3.4.4 OXYGEN AND OXYGEN-CONSUMING MATERIALS

Dissolved oxygen values in the Serpentine River ranged from a minimum 1.1 mg/L at Site 0300059 to a maximum of 17.6 mg/L at Site 1100049 (Table 11a). Such a large range of values was typical, although not necessarily to the same degree, of dissolved oxygen levels found throughout the Serpentine River. Low dissolved oxygen values occurred typically between May and November.

Percent saturation ranges were also large in the Serpentine River. Values ranged from 9.7% at Site 0300059 to 278.7% at Site 1100033 (Table 11a). These extreme values also were typical, although not necessarily to the same degree, of percent saturation values throughout the River. Such wide ranging values are typical in a stream with heavy algal production. These extremes can cause stress to aquatic life.

A slight impairment to salmonids occurs at dissolved oxygen levels of 6.0 mg/L(83). In comparing dissolved oxygen levels in the Serpentine River to this criterion, it is apparent that there are times when there are real concerns about oxygen levels in the river.

Spawning occurs in the Serpentine River (Figure 5) near Site 1100037, where dissolved oxygen levels were good, ranging from 8.0 to 14.7 mg/L. These levels will not impair salmonids(83).

Dissolved oxygen levels in Mahood Creek were also good, ranging from 7.5 mg/L to 13.4 mg/L at Site 1100056 (Table 13). Percent saturation values ranged from 76.3% to 135.2% at Site 1100056, indicating some stress to aquatic life could result, but certainly not in any degree close to that in the Serpentine River.

Dissolved oxygen values in Hyland Creek ranged from 8.5 to 10.8 mg/L (Table 12). In Latimer Creek, these ranged from 5.6 to 9.6 mg/L (Table 14). It was not possible to calculate percent saturation values in these two creeks. However, it is apparent that salmonids in Mahood, Latimer, and

Hyland Creeks have only slight to no impairment (i.e., ≥6.0 mg/L)(83) at all times.

No impairment to salmonids occurs at dissolved oxygen concentrations ≥8.0 mg/L(83). This appears to have been achieved in Hyland Creek at all times, and in Mahood and Latimer Creeks most of the time.

Staged provisional objectives for minimum dissolved oxygen values are proposed for the Serpentine River. The first objective is for the water quality to meet 6 mg/L dissolved oxygen from June to October. The second objective (long-term) would be implemented when dissolved oxygen levels consistently met the first level. The second stage would increase the objective value for dissolved oxygen to 8.0 mg/L from June to October. In Latimer, Hyland, and Mahood Creeks, the proposed provisional objective is that the minimum dissolved oxygen value should be 8.0 mg/L at all times. This objective may not always be met in Mahood or Latimer Creeks. In addition, dissolved oxygen levels in the Serpentine River and Latimer, Hyland and Mahood Creeks should be, as a minimum, 11.0 mg/L when larvae and/or alevin are present. This objective will likely be met in areas of the river system where spawning occurs.

These objectives apply to discrete samples or in-situ measurements taken outside the initial dilution zones of effluents, described in Section 2.4.1.

Remedial activities to increase dissolved oxygen levels in the lower reaches of the Serpentine River have been initiated. These activities take into consideration fisheries, agriculture, and flood control concerns. At present, the use of local diffusers to introduce air into the river is being evaluated.

3.4.5 BACTERIOLOGICAL QUALITY

Fecal coliform levels ranged from <20 to >24 000 MPN/100 mL at Site 0300057 in the Serpentine River (Table 11a), while median values were as high as 1 300 MPN/100 mL at Site 0300059 and 790 MPN/100 mL at Site 1100032. Values were also high in Mahood Creek, ranging from 330 to >2 400 MPN/100 mL at Site 0300056 (Table 13). Similar high levels were also found in Hyland Creek (Table 12) and Latimer Creek (Table 14). These high levels possibly originate from agricultural wastes.

The working criteria for livestock watering limit the concentration of fecal coliforms to 10 MPN/100 mL (90th percentile) for water used after disinfection only(7,30). For use of Serpentine River water for drinking and livestock watering, complete water treatment plus disinfection would be required; however, the B.C. Ministry of Health does not approve of the use of these waters for a drinking water supply. The working criteria for irrigation use are a geometric mean value of 200 MPN/100 mL, and a 90th percentile of 400 MPN/ 100 mL(30). These recent working criteria are not met, and are more restrictive than the approved water quality objectives for the Fraser River(82).

Therefore, staged provisional (long-term) objectives for fecal coliforms in the Serpentine River, Hyland Creek, Latimer Creek, and Mahood Creek are proposed. The first objective (long-term) is that the 30-day geometric mean should be less than 200 MPN/100 mL year-round to protect irrigation and livestock watering. In the short-term, the geometric mean should be ≤1000 MPN/100 mL from April to October and the maximum ≤4000 MPN/ 100 mL. These objectives apply to discrete samples, as the mean or 90th percentile of at least five weekly samples taken in a 30-day period, outside the initial dilution zones of effluents, described in Section 2.4.1

Domestic water licence holders should be advised that, at present, complete water treatment may be necessary for Serpentine River water prior to use and that the B.C. Minsitry of Health does not approve of its use for drinking water. Further monitoring of fecal coliform and fecal streptococci should be conducted to determine the present levels and sources of fecal contamination in the basin. This will indicate the feasibility of attaining the long term objectives.

3.4.6 SOLIDS

Dissolved solids values from near the mouth of the Serpentine River were significantly higher than those observed further upstream, due to saltwater intrusion. Saltwater influences, as indicated by high dissolved solids levels and specific conductivity measurements, have been evidenced as far upstream as Hyland Creek. In Mahood Creek (Table 13), dissolved solids were at a maximum of 338 mg/L at Site 0300056. In Hyland Creek and Latimer Creek, values were about one-half this number (Table 12 and 14). The most restrictive dissolved solids criteria of 500 mg/L are to protect drinking water(7) and irrigation(76).

Suspended solids values were relatively uniform throughout the system, with a maximum value of 85 mg/L at Site 1100041. Maximum suspended solids values in the creeks were 129 mg/L at Site 0300056 in Mahood Creek (Table 13), 18 mg/L in Hyland Creek (Table 12), and 14 mg/L in Latimer Creek (Table 14).

Bourque and Hebert (1982)(25) examined suspended solids data between 1974 and 1975, finding values ranging from 5 mg/L to 73 mg/L.

The B. C. water quality criteria for particulate matter(14) limit the quantity of induced suspended solids to not exceed 10 mg/L when background levels are less than 100 mg/L, nor to be more than 10% of background when background is greater than 100 mg/L, for the protection of aquatic life. In the Serpentine River, Mahood (Bear) Creek, Hyland Creek, and Latimer Creek, the provisional objectives proposed are that induced levels of suspended solids should not exceed 10 mg/L when background levels are less than 100 mg/L, nor should these levels be more than 10% of background when background is greater than 100 mg/L. These objectives apply to discrete samples collected outside the initial dilution zones of effluents described in Section 2.4.1.

In addition, to protect salmonid spawning areas, there should be no significant (95% confidence level) induced benthic sedimentation on the basis of accumulation by weight for particles <3 mm.

High turbidity values were associated with the periods September to March, and July. During five sampling periods (July to September 1974, July 1975, March 1976, September 1976 to January 1977, and November 1978) high turbidity values were recorded throughout the Serpentine River system. This underlines the contribution of stormwater runoff to water quality within the river. The maximum turbidity (192 NTU) was at Site 1100049 (Table 11a). It should be noted that turbidity frequently exceeded the maximum acceptable level of 5 NTU for drinking water, indicating that filtration or its equivalent would be needed to remove suspended solids prior to drinking, during much of the year.

The maximum turbidity level in Mahood Creek was 104 NTU at Site 1100056 (Table 13). In Latimer Creek the maximum level was 7.3 NTU (Table 14) while the only measurement in Hyland Creek was 3.8 NTU (Table 12).

The B.C. criteria for turbidity(14) are that induced levels should not be more than 5 NTU when background levels are less than 50 NTU, nor be more than 10% of background when background levels exceed 50 NTU. A provisional water quality objective is proposed for turbidity in the Serpentine River, Mahood Creek, Latimer Creek, and Hyland Creek. The objective is that the induced turbidity levels should not be more than 5 NTU at a background level less than 50 NTU, nor be more than 10% of background if background exceeds 50 NTU.

The objective applies to discrete samples taken outside the initial dilution zones of effluents, described in Section 2.4.1.

3.4.7 POLYCHLORINATED BIPHENYLS (PCBs)

In Section 3.3.3, it was calculated that PCBs could be increased in Mahood Creek from a discharge from B.C. Hydro. Concerns were expressed that ambient levels could exceed the drinking water criterion of 3 μg/L(75) and the aquatic life criterion of 0.001 μg/L(76).

Of equal concern is the possibility that PCBs could be deposited with bottom sediments, thereby being available to enter the food web, eventually contaminating fish. Working water quality criteria for PCBs are 0.05 μg/g (dry weight) in sediments(75), 2 μg/g (wet weight) in edible fish tissues to protect human consumers(75) and 0.1 μg/g (wet weight) in whole fish to protect fish eating mammals in water(72). For the Fraser River, Swain and Holms proposed 0.03 μg/g (dry weight) for bottom sediments and 0.5 μg/g (wet weight) in fish muscle, to protect aquatic organisms(82). The former had been derived arbitarily to reflect background Fraser River concentrations while the latter was based on 1972 criteria(26) which were greater than the detection limit of 0.3 μg/g (wet weight)(82). In the absence of site-specific data for PCBs, the use of more restrictive criteria is warranted as a conservative approach to establishing provisional objectives.

For these reasons, provisional water quality objectives are proposed for PCBs in the water column, sediments, and in fish muscle and in whole fish in Mahood Creek and in the Serpentine River. The objectives are that the maximum PCB concentrations should not exceed 0.001 μg/L in the water column, 0.03 μg/g (dry-weight) in the bottom sediments, 0.5 μg/g (wet-weight) in muscle of large fish consumed by man, and 0.1 μg/g (wet weight) in whole small fish subject to predation.

The objectives apply to water or sediment samples collected outside the initial dilution zones of effluents, described in Section 2.4.1. The objective for fish applies to fish of any species caught in any part of Mahood Creek or the Serpentine River, including the initial dilution zones of effluents. The term PCBs applies to the sum of Aroclor 1242, 1254, and 1260, which may be present in water, sediment, or fish. The achievement of the objective for bottom surface sediments should be determined from the average of at least three replicate sediment samples taken from the same site.

It is recognized that some of the proposed objectives are lower than analytical detection limits. It is recommended that these detection limits be lowered. In the interim, values below detection will be considered as meeting the objectives.

3.4.8 CHLOROPHENOLS

In March 1984, a fish kill (>5000) occurred in Hyland Creek as the result of a spill of 45 000 litres of pentachlorophenol and tetrachlorophenol. Chlorophenols are not discharged normally into the Serpentine River or its tributaries. The 1984 spill was an isolated incident according to investigations carried out by Waste Management staff. Therefore, no objectives will be proposed for chlorophenols.

3.5 RECOMMENDED MONITORING

Water quality objectives have been proposed on Hyland, Latimer, and Mahood Creeks and on the Serpentine River. It is recommended that as a minimum, objectives should be checked at Site 0300056 on Mahood Creek, at sites near the mouths of Latimer and Hyland Creeks, and at Sites 0300059 and 0300057 on the Serpentine River. Additional sampling sites should be used when the objectives are exceeded to determine the extent of the problem. A minimum sampling frequency of five weekly samples is recommended. Samples should be analyzed for pH, temperature, dissolved oxygen, specific conductivity, ammonia, nitrite, nitrate, fecal coliforms, fecal streptococci, turbidity, suspended and dissolved solids, periphyton chlorophyll-a, dissolved orthophosphorus, total phosphorus, and total and dissolved copper, iron, manganese, and lead. However, resources and other regional priorities will determine the exact program.

Two special studies have been recommended for the Nicomekl River (Section 4.5): one to determine effects of agriculture and a second to examine the impact of urban stormwater runoff. The findings of these special studies should be applicable to the Serpentine River watershed for estimating levels and sources of fecal contamination.

3.6 CONCLUSIONS

There are four permitted point source discharges to Mahood Creek, one to Hyland Creek, and none to Latimer Creek or the Serpentine River. The discharge into Mahood Creek could increase suspended solids, oil and grease, iron, and PCBs. The discharge into Hyland Creek might increase suspended solids.

The greatest concern in this watershed is the contribution from agricultural sources, which increases the availability of nutrients. These in turn can increase algal production, and subsequently cause dissolved oxygen elevations and depressions.

The pH in the Serpentine River can vary as much as 3.0 pH units from minimum to maximum . Alkalinity values can be from moderate to low, while the water would be classed as soft. Some high metal values for total aluminum, copper, lead, iron, manganese, and zinc were thought to be naturally occurring. Phosphorus values were high enough to cause algal blooms, if phosphorus is the limiting factor. Ammonia and nitrite toxicity were not thought to be a concern. Large variations occur in dissolved oxygen and percent saturation values, likely due to algal photosynthesis, respiration, and decomposition. Fecal coliform values were too high to would permit drinking without complete treatment. Dissolved solids reflected the influence of saltwater intrusion near the mouth, but were not so high in the upper reaches as to restrict any water uses.

4. NICOMEKL RIVER

The Nicomekl River has a drainage area of 175 km². It receives runoff from the southeast slope of Clayton Upland and the Langley Upland (Figure 5). Three of the major tributaries within the drainage area are Anderson Creek with a drainage area of 24.7 km², Murray Creek with a drainage area of 27.1 km², and the old logging ditch with a drainage area of 7.7 km² (Figure 5). The area is underlain by stoney marine clays, except in the uplands around Anderson Creek. This portion of the drainage basin is underlain by 27 m of sand and gravel which is an unconfined aquifer recharged directly by precipitation in the area.

4.1 HYDROLOGY

The locations of flow gauging sites within the Nicomekl drainage basin are on Figure 3. These sites are situated on Anderson Creek (08MH104), Murray Creek (08MH107, 08MH129), and the Nicomekl River below the confluence of Anderson Creek (08MH050) and Murray Creek (08MH105).

Historical average daily flows have ranged from 0.062 m³/s to 28.3 m³/s at Site 08MH105 and, for a later period of record, from 0.125 m³/s to 35.4 m³/s at Site 08MH050, both on the Nicomekl River. For Murray Creek, average daily flows ranged from 0.011 m³/s to 14.5 m³/s at Site 08MH107 and for a later period of record, from 0.001 m³/s to 19.7 m³/s at Site 08MH129. In Anderson Creek, average daily flows have ranged from 0.108 m³/s to 17.2 m³/s.

Ten-year and two-year, seven-day average low flow values were calculated to be 0.13 m³/s and 0.24 m³/s at Site 08MH050 on the Nicomekl River below Anderson Creek; 0.089 m³/s and 0.117 m³/s at Site 08MH105 on the Nicomekl River below Murray Creek; 0.13 m³/s and 0.149 m³/s at Site 08MH104 on Anderson Creek; and 0.001 m³/s and 0.006 m³/s at Site 08MH129 on Murray

Creek. At Site 08MH107, based on data from 4 years, the two-year return flow was 0.025 m³/s.

4.2 WATER USES

Sixty water licences located within the Nicomekl drainage area (Figures 3 and 3b) have been issued for an annual withdrawal of 2 272 dam³. Forty-four licences were issued for the withdrawal of 2 239 dam³ for irrigation (98.5% of the annual withdrawal), four licences were issued for the withdrawal of 18.4 dam³ (0.8% of the annual withdrawal volume) for land improvement (construction of ponds), seven licences were issued for the withdrawal of 9.8 dam³ (0.4% of the annual withdrawal volume) for stock watering, three licences were issued for the withdrawal of 4.15 dam³ (0.2% of the annual withdrawal volume) for drinking water, and two licences were issued for the withdrawal of 1.23 dam³ (0.1% of the annual withdrawal volume) for industrial use (for a greenhouse and a fish culture operation).

Steelhead and cutthroat trout utilize the Nicomekl River system. Coho salmon spawn in the Nicomekl River (Figure 5) between 21 km to 23 km and 26 km to 30 km upstream from Mud Bay. Spawning occurs between 0.5 km to 10.6 km on Anderson Creek and from 1 km to 8.6 km on Murray Creek, upstream from their confluences with the Nicomekl River.

Coho in the Nicomekl River have demonstrated similar patterns of population fluctuations (Table 15) as those described for the Serpentine River (Section 3.2). Spawning in this system begins in early November, a half month later than the Serpentine River, with the peak of spawning occurring in late November and ending in late December.

There is no primary-contact recreation in the Nicomekl River.

4.3 WASTE DISCHARGES

The locations of operations discharging effluent within the Nicomekl drainage basin are represented by their permit numbers, issued pursuant to the Waste Management Act, in Figures 3 and 3b.

4.3.1 LANDFILLS

4.3.1.1 Rocla Concrete Pipes, Langley (PR 4965)

This company operated a 4.9 ha refuse site located about one km north from the Nicomekl River in Langley (Figure 3b). The company was issued a permit in 1978 for the disposal of waste concrete (80%) and broken concrete pipe (20%) at a rate of 2 m^3/d. The location of the site is just south from the Fraser River dyke highway in North Langley. The site was estimated to have a service life of three years. The covering requirements for this operation were that wastes were to be covered every 40 days. No drainage problems have been reported in connection with this operation. The highest recorded water table was 3 m from the surface.

The landfill, operated by Flexlox Ltd. for Rocla Concrete Pipes, was closed in 1984. The nature of the landfilled material should not result in a negative impact on the Nicomekl River.

4.3.1.2 Township of Langley (PR 1898)

The Township of Langley operated a municipal landfill until 1978. It was located about one km south from the Nicomekl River, equidistant from Anderson and Murray Creeks (Figure 3b). The landfill was located in an excavated pit and received refuse from a population equivalent of 50 000 persons.

Leachate generated at the landfill discharged into a minor tributary (formerly a salmon spawning stream) of the Nicomekl River. Elevated levels of ammonia, COD, total organic carbon, pH, and specific conductivity were reported in samples collected from the tributary downstream from this operation. Fungal blooms (*Leptomitaceas*) have been observed in the tributary immediately adjacent to the landfill operation. It has been proposed that the tributary be diverted around the landfill and a leachate collection system be installed. The impact on the Nicomekl is not known but is probably of concern since fungal growths have been observed at least one kilometre downstream.

4.3.2 COOLING WATER

4.3.2.1 Mansonville Plastics Ltd. (PE 4413)

This polystyrene foam manufacturing plant is located just north from the Nicomekl River and downstream from its confluence with Anderson Creek (Figure 3b). The company was issued a permit in 1976 to discharge cooling water to the Nicomekl River and boiler blowdown to a steel tank in a gravel pit. Permit PE 4413 allows the discharges at a maximum rate of 109 m^3/d and 0.09 m^3/d, respectively. The minimum dilution available to the cooling water after complete mixing, based upon the 10-year, seven-day low flow of 0.13 m^3/s and the maximum discharge rate, would be 103:1, or 190:1 with the two-year low flow. The cooling water must be discharged at a temperature less than 32° C. Values for the flow of the cooling water collected from 1977 to 1979 ranged from 16.4 to 33.7 m^3/d (mean, 25.1 m^3/d). No cooling water discharges have occurred since 1979.

The cooling water was treated by discharging it to a wide ditch containing a flotation trap, screens, and two dams 3 m apart. Screens and flotation traps were used to capture any polystyrene chips before flows entered the Nicomekl River.

It is not known what effect this effluent had on the Nicomekl River since no data on the actual temperature of the discharged cooling water have been recorded. However, the available dilution presumably ensured that there were no appreciable effects on the water quality of the Nicomekl River.

Boiler blowdown is drained daily. The discharge enters an exfiltration pond via a 1.5 m x 0.6 m steel tank with perforations on the lower portion of the tank to allow the discharge to enter the pond. No further information about the boiler blowdown water was available but, given the very small quantity and its discharge to ground, no effects on surface water quality are probable.

4.3.3 SOIL DISPOSAL SYSTEMS

4.3.3.1 Ambassador Industries Ltd., Langley (PE 5269)

This company is located about two km south from the Nicomekl River and equidistant between Anderson and Murray Creeks. It discharges domestic sewage from a commercial complex at an average flow rate of 19 m^3/d after treatment in an aeration treatment plant with a capacity of 18.6 m^3. The treated sewage is discharged to two disposal fields (minimum of 153 m of tile each). Permit PE 5269 requires that the effluent contain no more than 45 mg/L BOD_5 and 60 mg/L suspended solids. Stormwater from the adjacent paved parking lot is disposed of in rock pits.

Data collected for the treated effluent from this operation are in Table 16. These limited data indicate that the limits were not met with respect to BOD_5 removal. Effluent from this operation should not negatively impact water quality in the Nicomekl River, Anderson, or Murray Creek owing to the distance from the point of discharge to these water bodies.

4.3.3.2 Willowbrook Meats Ltd., Langley (PE 2072)

This company, located near the headwaters of the Nicomekl River, stopped operating in 1985. Permit PE 2072 was first issued in 1976 for the discharge of uncontaminated cooling water, which originated from a refrigeration compressor. The cooling water entered a perimeter drainage and stormwater runoff ditch, at an average weekly discharge rate of 45.5 m^3. The ditch then discharged to the Nicomekl River. The process effluent was trucked to a municipal treatment facility in Fort Langley (PE 4339) as surface irrigation or sub-surface disposal was not a viable alternative, due to the nature of the soil.

4.3.3.3 Big A Tank Services Ltd. (PE 5968)

This company operates throughout the Fraser Valley, injecting effluent from a small-scale abattoir (Westcoast Reductions) and confined livestock facilities into the ground at different locations to a depth of about 30.5 cm. This occurs over the growing season from April to October. The wastes are hauled to a treatment facility in Langley during the rest of the year.

The permittee is required to submit a monthly schedule to the Regional Waste Manager outlining the date and location of discharge, nature and quantity of waste applied and area to which waste was applied. Permit PE 5968 limits the maximum flow rate to 180 m^3/d.

This operation has stopped using effluent from the abattoir, but continues to haul the washwater from the abattoir to the Langley sewage treatment facility. The manure from the confined livestock facility is stored in pits and applied to the fields throughout the Lower Mainland. This operation would therefore have no direct impact on the water quality of the Nicomekl River.

4.3.3.4 Western Paving Ltd., (PE 2367)

This conventional gravel washing plant, located one km to the west of Anderson Creek and about four km upstream from its confluence with the Nicomekl River (Figure 3b), ceased operations in 1985. Washwater flowed at a permitted rate of 2 050 m^3/d to a settling pond where the supernatant exfiltrated to other ponds and the surroundings. Water was recycled to the plant from an adjacent pond into which no gravel washwater was added. The plant held Permit PE 2367 since 1973.

Data in Table 17 indicate that the discharge rate allowed by the permit was not exceeded between 1974 and 1978. This settling/recycle system, with no positive discharge, would not have affected the water quality of Anderson Creek.

4.3.3.5 Noel Booth Elementary School, Langley (PE 6323)

This elementary school is located west from Anderson Creek, and about four km upstream from its confluence with the Nicomekl River. It discharges domestic sewage from a population projected to range from 360 to 480 students. The wastewater is discharged to a 30 m^3 septic tank and then to two fields with 549 m of tile each, located approximately 97 m from Anderson Creek. At this location, Anderson Creek dries up during the summer; however, there would be little or no discharge to the tile system during this time.

The soil in the area consists of loamy sand and gravel. Percolation rates were found to average between 11 cm/minute and 4.4 cm/minute, depending on soil depth. No hardpan or groundwater was found to a depth of 3.7 m. Permit PE 6323 restricts the maximum discharge of treated wastewater to 24.5 m^3/d.

This system should not affect Anderson Creek due to its distance from the creek, duration of operation (when flows exist in the creek), and the small volume of wastewater discharged to ground.

4.3.3.6 School District No. 35 Brookswood Junior Secondary School, Langley (PE 3148)

This school is located about one km east from Anderson Creek, and about four km upstream from its confluence with the Nicomekl River. Permit PE 3148 was issued in 1974 to allow a maximum discharge of 54.6 m^3/d of septic tank effluent from the school, which has a student population of 1 000. The domestic sewage is treated in a septic tank (capacity: 45.6 m^3/d) prior to being discharged to two tile fields (840 m each).

This operation should not affect water quality in Anderson Creek due to its distance from the creek, duration of operation, and the small volume of wastewater discharged to ground.

4.3.3.7 Walter H. Arber and George A. Smith (PE 218)

This 37-unit mobile home park is located just west from Anderson Creek and 3 km upstream from its confluence with the Nicomekl River. Domestic sewage is treated in a 63.6 m^3 septic tank prior to disposal in a 885 m tile field. Permit PE 218, issued in 1968, allows the discharge of 29.55 m^3/d. This effluent should not affect the water quality of Anderson Creek or McPherson Creek (a tributary) as it is discharged to a soil absorption system, and the volume of wastewater discharged is small.

4.3.3.8 Old Yale Investments (1982) Limited (PE 4690)

This poultry processing plant is located near the headwaters of Anderson Creek. It operates from April through mid-December, with peak production in mid-November reaching 13 600 kg/d. The permit, issued in late 1977, was ammended in June 1983 to allow the following maximum values: flow, 114 m^3/d; suspended solids, 75 mg/L; total solids, 500 mg/L; BOD_5, 200 mg/L; oil and grease, 40 mg/L; and pH, 5-7. The amendment also allowed the company to install a blood recovery tank, coarse and fine screens, chemical coagulation, dissolved air flotation, a facultative lagoon, and sprinklers for spray irrigation of effluent on hay crops on adjacent land.

No data are available to determine if the new treatment works will ensure no adverse effects on water quality in Anderson Creek. Monitoring upstream and downstream from areas of spray irrigation is recommended when spray irrigaton is taking place.

4.3.4 SURREY COOPERATIVE ASSOCIATION, Surrey (PE 4262)

The Surrey Cooperative Association bulk petroleum storage plant is located about four km downstream from Anderson Creek on the Nicomekl River (Figure 3). Permit PE 4262 allows the discharge of an average 19.3 m^3/d and a maximum of 430 m^3/d of stormwater to an unnamed ditch which flows to the Nicomekl River. At the maximum discharge rate and at the 10-year, seven-day low flow of 0.13 m^3/s in the Nicomekl River below Anderson Creek, a minimum dilution of 26:1 is available, or 48:1 with the two-year low flow. The actual minimum dilution is probably much greater because it is very unlikely that the maximum stormwater discharge would occur during low streamflow periods. An average stormwater discharge would be diluted about 600:1 during the 10-year low flow. The permit allows concentrations of 20 mg/L suspended solids and 5 mg/L oil and grease, with a pH range from 6.5 to 8.5.

The stormwater is treated in an oil separator with a capacity of 10.8 m^3. It provides a retention time of 13 hours, based on an average storm, and 0.6 hours based on the maximum storm.

Limited data for the operation are included in Table 18. The mean oil and grease value of 37 mg/L for all values in Table 18 indicates that the oil separator was not reducing values adequately in the discharge. However, the large dilution available in the Nicomekl River may have precluded any measurable or noticeable effect on the river.

4.3.5 DIFFUSE SOURCES

Feedlots within the Nicomekl River watershed registered with the Ministry of Agriculture's Beef Assurance Program are on Figures 3 and 3b. The largest of these operations is located at the headwaters of Anderson Creek (267 yearlings). One facility was located on the Nicomekl River near Langley (105 cattle: 52 cows, 48 calves, 4 yearlings, 1 finishing cattle - Figure 3b), and one was located within the floodplain near the mouth of the river between the Serpentine and Nicomekl Rivers (121 cattle: 57 cows, 64 calves - Figure 3).

An estimate of phosphorus and nitrogen loadings to the Nicomekl River is in Table 28. It was estimated that 10 700 kg of nitrogen and 1 000 kg of phosphorus could be generated and potentially transported to the river. Assuming 100% transmission to the river, which is unlikely, the nutrient levels in the Nicomekl would increase as indicated below for different flows and release periods:

Increase (mg/L) With Varying River Flows
and Release Periods

Constituent	River Flow (m^3/s)	4 weeks	2 weeks	1 week
Nitrogen	35.4	0.12	0.25	0.5
	28.3	0.16	0.31	0.62
	0.24	18.4	36.9	73.7
	0.13	34	68	136
Phosphorus	35.4	0.012	0.023	0.047
	28.3	0.015	0.029	0.058
	0.24	1.72	3.44	6.89
	0.13	3.18	6.36	12.7

These data indicate that phosphorus and nitrogen could be increased significantly at low flows, and even at peak flows when these nutrients likely would be released. Longer release periods and smaller rates of transmission would reduce these impacts. Actual riverine conditions are discussed in Section 5.4.3.

Stormwater runoff from Langley could also be a source of contaminants such as lead, zinc, fecal coliforms, and PCBs. The impact of these contaminants would depend upon the volume of stormwater discharged. No attempt will be made to estimate these loadings for the purpose of this assessment.

In addition, septic tanks discharging to tile fields are potential sources of nutrients and fecal coliforms. The loading from these sources will depend upon the number of systems in the watershed, the distance each is from the river, the type of soil each is located in, and the volume treated in each system. Estimating these loadings is beyond the scope of this assessment.

4.4 WATER QUALITY AND PROPOSED PROVISIONAL WATER QUALITY OBJECTIVES

Several studies have reported on water quality within the Nicomekl River drainage basin(3,25,28,33). This report incorporates the findings of those studies and asesses water chemistry data collected at 13 sites on the Nicomekl River and two sites on both Anderson Creek and Murray Creek (see Figures 3, 3b) over an eleven-year period (1972-1983). No data have been collected since 1982. From these data, water quality objectives for the Nicomekl drainage basin are proposed. Data collected from 1979 to 1983 for water chemistry are summarized in Tables 19, 21, 22, those for sediment chemistry are in Tables 20 and 23.

Present water uses which should be protected in the Nicomekl River include: irrigation, stock watering, and the protection of aquatic life and wildlife.

4.4.1 pH AND BUFFERING CAPACITY

Median pH values ranged from 7.2 at Sites 0300060 to 7.75 at Site 1100003 on the Nicomekl River, from 7.6 to 7.8 in Anderson Creek, and from 7.45 to 7.5 in Murray Creek. A general seasonal trend was observed at all sites throughout this system. Median pH values between January and April (6.9 to 7.7) were lower than those collected between May and August (7.5 to 8.26). As was observed in data from the Little Campbell River, low pH values occurred during periods of low flow, high temperatures, and high ammonia values. The lower values in the January to April period reflect the presence of large quantities of runoff which are poorly buffered due to the short residence time on the soil.

Geographically, samples collected from sites (1100002, 0300060, 1100003, 1100004, 1100005) between Cloverdale and the mouth of the river (Figure 3) had lower median pH values than from other sites on the Nicomekl River, Anderson Creek, or Murray Creek. The lowest values for pH ranged from 6.4 to 6.8 at these five sites compared to values of 6.9 to 7.2 in upper reaches of the Nicomekl River, 7.2 in Murray Creek, and 7.0 in Anderson Creek. Most values were above the minimum working criterion for pH of 6.5 to protect aquatic life and drinking water(31,34).

Values greater than the pH range for the protection of aquatic life (6.5 to 9.0)(31) occurred in three of thirty-five samples collected at Site 0300060 (value range: 9.0 to 9.3) and in three of forty-one samples collected at Site 1100003 (value range: 9.0 to 9.2). These values occurred in May 1977, July and August, 1982 at Site 0300060 and in September 1974, July 1975 and August 1979 at 1100003. Both of these sites are located near the mouth of the Nicomekl River. Since the upper limit of the working criteria for drinking water is 8.5(34), a larger number of samples exceeded this limit at the two sites over a period of years. The number of excursions were six at Site 0300060 and seventeen at Site 1100003. In addition, one excursion (of 16 samples) was recorded at Site 0300064 on Murray Creek and seven (of 42) at Site 1100002 near the mouth of the Nicomekl River. There are no licenced drinking water withdrawals in the lower reaches of the Nicomekl River. The pH seems to be naturally high in some areas of the basin. A provisional water quality objective is proposed to protect drinking water supplies and aquatic life. The provisional objective proposed is that the pH should be from 6.5 to 8.5 in the Nicomekl River and its tributaries. If upstream values are greater than 8.5, values should not change downstream from a discharge or series of discharges by more than 0.2 units. These objectives apply to all discrete samples collected in the Nicomekl River, and do not apply in initial dilution zones of effluent described in Section 2.4.1.

Mean alkalinity values at sites near the mouth of the river to Cloverdale (1100002, 1100003, 1100004) ranged from 54.3 mg/L to 76.6 mg/L, indicating a higher buffering capacity than at sites further upstream (0300060, 1100005, 1100006, 0300061, 0300062, 1100007; mean value range: 46.7 mg/L-62.5 mg/L), on Anderson Creek (49.8 mg/L - 40.3 mg/L) and Murray Creek (37.7 mg/L - 41.4 mg/L). Alkalinity values less than 40 mg/L were associated with the period between January and April. The highest alkalinity values usually occurred between June and November, during periods of low flow and increased biological activity. Anderson Creek and Murray Creek also displayed similar seasonal tendencies. However, in the period between September and November, alkalinity values from sites on Murray Creek decreased to less than 40 mg/L.

4.4.2 HARDNESS AND METALS

Water in the Nicomekl River upstream from about the Township of Langley in Anderson Creek and in Murray Creek would be classified as soft (having a hardness value less than 75 mg/L of $CaCO_3$). Higher concentrations were found at sites near the mouth of the Nicomekl River which indicate the presence of salt water entering the system from Boundary Bay and Mud Bay.

Seasonal variability in hardness data was more pronounced near the mouth of the river than at sites near the Township of Langley and further upstream. Typically, values increased to a maximum between July and September followed by a decrease in samples collected between October and December. A factor contributing to these fluctuations is higher flows in the river which prevent saltwater intrusion in the lower reaches of the Nicomekl River.

4.4.2.1 Metal Values in the Water Column

A total of 20 total aluminum measurements were made on the Nicomekl River in 1982 at Sites 0300060 near the mouth, 0300061 downstream from Langley, and 0300062 upstream from Langley. The values ranged from 0.03 to 0.77 mg/L, with 19 of 20 values exceeding the working criterion of 0.10 mg/L for the protection of aquatic life(5). However, a water quality objective is not proposed for aluminum since it is believed to be naturally occurring and not the result of anthropogenic activity.

Dissolved boron values collected near the mouth of the Nicomekl River at Sites 1100002, 1100003, and 1100005, during the period between May and August ranged from <0.1 mg/L to 1.3 mg/L. Swain and Alexander(3) had reported a median value of 0.1 mg/L (n=19) at Site 1100003. Higher boron values near the mouth of the river can be attributed to the intrusion of saltwater (seawater contains ≈ 4.5 mg/L boron) from Mud Bay. The working water quality criterion to protect sensitive crops is 0.5 mg/L(76), and 5 mg/L for stock watering. Thus there may be times when the river near the mouth should not be used to irrigate some crops. These criteria, and that for drinking water (5.0 mg/L)(7), were not exceeded at any sites on Anderson Creek or Murray Creek.

The highest concentrations of total chromium were at Site 0300060 near the mouth of the Nicomekl River (0.016 mg/L). Most values were below the detection limit of 0.01 mg/L. The working water quality criteria are 0.02 mg/L for fish, 0.002 mg/L for phytoplankton and zooplankton(76), 0.05 mg/L for drinking water(7), 1 mg/L for livestock, and 0.1 mg/L for irrigation(76). Thus there may have been times when phytoplankton and zooplankton were affected. Detection limits were generally too high to determine if this concern exists along the river. A similar concern exists in Murray Creek (maximum of 0.013 mg/L at Site 0300064) and Anderson Creek (maximum value of 0.007 mg/L at Site 0300063). Additional monitoring should be carried out to determine if these levels are natural and if not, their source.

Median and mean total copper values for the Nicomekl River decreased from sites near the mouth (Site 0300060: 0.004 mg/L and 0.006 mg/L; Site 1100003: 0.005 mg/L and 0.006 mg/L) to sites upstream (Site 0300062: 0.002 mg/L and 0.0018 mg/L; Site 1100007: 0.0025 and 0.005). Median and mean total copper varied little in Anderson Creek (Site 1100017: <0.001 mg/L and 0.002 mg/L) and in Murray Creek (Site 1100022 mean and median values: 0.003 mg/L, Site 0300064 mean and median value: 0.003 mg/L). There were no seasonal trends observed in copper values obtained at any site within the Nicomekl River, Anderson Creek, or Murray Creek.

Provisional B.C. criteria for total copper concentrations(66) for stock watering (0.3 mg/L) and irrigation (0.2 mg/L) were not approached in any of the samples collected on the Nicomekl River, Anderson Creek or Murray Creek. However, the criteria for the protection of aquatic life (30-day mean: 0.002 mg/L if hardness <50 mg/L; maximum: 0.007 mg/L, 0.011 mg/L and 0.021 mg/L when hardness, as $CaCO_3$, is 50 mg/L, 100 mg/L, and 200 mg/L, respectively) were exceeded in September 1975 at Sites 0300062 (0.02 mg/L) and 0300061 (0.02 mg/L) on the Nicomekl River, at Site 0300063 (0.02 mg/L) on Anderson Creek, and Site 0300064 (0.02 mg/L) on Murray Creek; in July 1979 the criteria were exceeded at Sites 1100006 (0.018 mg/L), 1100007 (0.016 mg/L), and 1100003 (0.016 mg/L) on the Nicomekl River, and at Site 1100022 (0.016 mg/L) on Murray Creek.

Although high values have been measured at several sites, values less than the criterion for the maximum value have been measured frequently. The high copper values were found at most sites on Murray and Anderson Creeks, and the Nicomekl River at the same time period. This implies that high copper values are natural throughout the watershed at the same time.

Swain and Alexander(3) had reported lead values at Site 1100003 to range from <0.001 mg/L to 0.012 mg/L (0.002 mg/L median). This is typical of values found at most of the other Nicomekl River sites (Table 19). The highest value for Anderson Creek and Murray Creek was 0.005 mg/L at Site 1100017 (Table 21) and Site 0300064 (Table 22), respectively. Water quality criteria are 0.05 mg/L for raw drinking water(6,84), 0.004 mg/L for aquatic life with minimum hardness of 40 mg/L(84), 0.2 mg/L for irrigation(76,84), and 0.1 mg/L for wildlife and livestock watering(76,84). This indicates that lead values in only the Nicomekl River exceeded the most sensitive criteria for the protection of aquatic life on certain occasions. Downstream from the Township of Langley, at Sites 0300061 and 1100006, total lead values over a period of years exceeded the aquatic life criterion on one of thirty occasions and two of seven occasions, respectively. The criterion was exceeded in two of seventeen samples collected at Site 1100005, two of thirty-seven at Site 1100003, three of thirty-nine at Site 0300062 and was exceeded in one of thirty-five samples collected at Site 0300060.

Stormwater could be entering the Nicomekl River from Langley. Therefore, a provisional objective is proposed for total lead to protect aquatic life. The objective is that the average value should not exceed 0.005 mg/L and the maximum should not exceed 0.010 mg/L. The objective (infrequently exceeded in the past) applies to the Nicomekl River, to samples collected outside the initial dilution zones of effluents described in Section 2.4.1.

All mean total iron values sampled at sites on the Nicomekl River, Anderson and Murray Creeks exceeded the criterion of 0.3 mg/L for drinking water use(7) and for the protection of aquatic life(76), but were less than the criterion for irrigation use (5 mg/L to 20 mg/L)(76). The criterion for drinking water is based on aesthetic considerations, not health. The maximum values of 5.5 mg/L at Site 0300062 on the Nicomekl River and of 8.6 mg/L at Site 1100022 on Murray Creek exceeded the criterion of 5 mg/L for continuous irrigation use on all soils.

Since these high values are frequent and occur throughout the watershed, we believe that they are naturally occurring. An example of the frequency of not meeting the drinking water and aquatic life criteria is given for Site 0300062 where 18 of 37 samples collected over a period of years exceeded the criteria. All samples from Murray Creek (Table 22) were at or exceeded the criteria level. At Site 0300063 on Anderson Creek (Table 21), 8 of 16 samples exceeded the criteria. Therefore, no objective for iron is proposed.

Swain and Alexander(3) reported total manganese values from 0.03 to 0.12 mg/L at Site 1100003 on the Nicomekl River. Values at Site 0300061 were as high as 0.27 mg/L (Table 19); however, most values at most sites have not exceeded 0.15 mg/L. The maximum value in Anderson Creek was 0.07 mg/L at Site 0300063. On Murray Creek, the maximum value was 0.05 mg/L at Site 0300064.

Working water quality criteria are 0.05 mg/L for drinking water (due to aesthetic considerations)(7), 0.1 mg/L to 1.0 mg/L for the protection of aquatic life(52), and 0.2 mg/L to 10 mg/L for irrigation(76). Thus, the drinking water criterion was equalled or slightly exceeded by maximum values in Anderson Creek and the Nicomekl River. The criteria to protect aquatic life were also exceeded in the Nicomekl River. The most restrictive irrigation criterion was exceeded at one site on the Nicomekl River.

The drinking water criterion was exceeded in nine of eighteen samples collected at Site 0300063 on Anderson Creek and on three of eighteen occasions at Site 0300064. The criterion for the protection of aquatic life was exceeded at Sites 0300061 (four of thirty-five occasions) and 1100003 (three of thirty-five occasions) on the Nicomekl River.

The highest total zinc values were recorded at Site 1100006, where a value of 0.13 mg/L was recorded (Table 19). Values as high as 0.11 mg/L were recorded at Sites 1100003 and 1100007. The highest value in Murray Creek was 0.12 mg/L at Site 1100022, while the highest value in Anderson Creek was 0.11 mg/L at Site 1100017. The fact that similar maximum zinc values were found throughout the watershed indicates that the zinc occurs naturally.

Working water quality criteria are 0.03 mg/L to protect aquatic life(76), 1.0 mg/L for irrigation water(76), 50 mg/L for livestock(76) and 5 mg/L for drinking water(7). Thus the criterion for aquatic life can be exceeded at times in all three water bodies. However, levels were well below criteria to protect other uses.

4.4.2.2 Metal Values in Sediments

Sediment samples were collected from three downstream sites (1100003, 0300060, and 1100005) and three upstream sites (1100006, 0300061, and 1100007) on the Nicomekl River. The data are summarized in Table 20. These values were compared to values for the Serpentine River, the Fraser River(21), B.C. Lake sediments(22), and urban stormwater sediments(24) in Table 23.

Concentrations of all of the metals in Nicomekl sediments were similar to concentrations found at the other locations (Table 20). Total cadmium, copper, lead, and zinc values in sediments from the Nicomekl River were lower than those from a stormwater catchment. This may reflect the lack of urban development within this drainage basin. Total cadmium, lead, and manganese values were similar in sediments from both the Serpentine and Nicomekl River. Total cobalt values in sediments from the Nicomekl River were marginally higher than those from the Serpentine River. These higher cobalt values may be attributed to unconsolidated deposits from a cobalt-bearing local granite source(2) within the drainage basin.

4.4.3 NUTRIENTS

4.4.3.1 Nutrient Values in the Water Column

Tables 19, 21 and 22 contain nitrogen values analyzed at eleven sites on the Nicomekl River and two sites on both Anderson Creek and Murray Creek. The majority of the samples were collected quarterly (February, May, September, November) over a period of years.

The highest ammonia value in the Nicomekl River was 0.525 mg/L at Site 0300062 (Table 19). Corresponding to this was a pH of 7.4 and a temperature of 5.8°C. This ammonia concentration was well below the provincial water quality criteria for maximum and average ammonia concentrations to protect aquatic life(69). Similarly, maximum values at other sites on the Nicomekl River, and in Anderson Creek and Murray Creeks were below the criteria.

A concern can exist for ammonia generated from animal wastes. Therefore provisional water quality objectives are proposed for total ammonia in the Nicomekl River, Murray and Anderson Creeks. Total and average values should not exceed values listed in Tables 29 and 30 which are the provincial criteria for ammonia(69). The objectives apply in all areas, except initial dilution zones of effluents described in Section 2.4.1. The average value is to be calculated from a minimum of five samples collected in a 30-day period.

The maximum nitrite value in the Nicomekl River was 0.127 mg/L in October 1982 at Site 0300060. A value of 0.11 mg/L was recorded also in the same month. At chloride concentrations of 3 mg/L (minimum value in Nicomekl River), B.C. criteria for nitrite are 0.04 mg/L as a 30-day average value and 0.12 mg/L as a maximum value(69). Except for the high levels, recorded nitrite values did not exceed the 30-day average value. Maximum nitrite values in Anderson and Murray Creeks were less than both criteria.

Owing to the seasonal use of the Nicomekl River by salmonid populations, the fact nitrite can be formed when ammonia is oxidized, and the timing of values exceeding some criteria for the protection of aquatic life, provisional objectives for nitrite are proposed which are the same as the provincial nitrite criteria(69). The objectives are as follows:

Chloride Concentration mg/L	Maximum Nitrate Concentration mg/L	30-day Average Nitrite Concentration mg/L
<2	0.06	0.02
2-4	0.12	0.04
4-6	0.18	0.06
6-8	0.24	0.08
8-10	0.30	0.10
>10	0.60	0.20

The objectives apply to the Nicomekl River, Anderson and Murray Creeks, except in initial dilution zones described in Section 2.4.1. The average value is to be calculated from a minimum of five samples collected over a 30-day period.

All nitrate values in Anderson and Murray Creeks and in the Nicomekl River were below the B.C. criterion of 10 mg/L for raw drinking water supplies(69). This is the most sensitive use with respect to nitrate.

Phosphorus concentrations were highest at Sites 1100002, 1100003 and 0300060 near the mouth of the Nicomekl River and decreased at sites further upstream and on Anderson and Murray Creeks (Tables 19,21,22).

The highest dissolved ortho and total dissolved phosphorus values were 0.394 mg/L and 0.437 mg/L, respectively, at Site 1100005 in the Nicomekl River. These quantities of phosphorus are sufficient to cause heavy algal production, assuming that phosphorus is the limiting nutrient. Other factors which would have a bearing on algal growth would be availability of suitable substrate, adequate light, and the river velocity. High phosphorus values were also found in Murray Creek, but not at the same magnitude in Anderson Creek. Nevertheless, phosphorus concentrations were at high enough levels to cause algal growth, given the previous assumptions.

The water quality criterion for nutrients and algae in streams limits the chlorophyll-*a* levels to 100 mg/m^2 chlorophyll-*a* for the protection of aquatic life(9). No chlorophyll-*a* data were available for the Nicomekl River, Anderson Creek, or Murray Creek. Since phosphorus and nitrogen can enter the water from agricultural practices, a provisional objective of 100 mg/m^2 chlorophyll-*a* is proposed, applicable to naturally-growing periphytic algae. This objective is to be evaluated from the average of at least five replicates collected on the same date. The objective applies to all parts of Anderson and Murray Creeks and the Nicomekl River, except initial dilution zones of effluents described in Section 2.4.1. This objective, in the absence of data, may have to be a long-term objective. It is recommended that chlorophyll-*a* monitoring of natural substrates be conducted on a routine basis to determine if this proposed objective is appropriate.

4.4.3.2 Nutrient Values in Sediments

Sediment samples were analyzed from three sites (1100003, 1100005, 1100006) on two occasions (June, July) in 1979 and from three sites (0300060, 0300061, 1100007) in 1983 (Table 20). The highest Kjeldahl nitrogen (3 mg/g), total phosphorus (1.4 mg/g), organic carbon (26 mg/g) and inorganic carbon (10 mg/g) values were found at Site 0300060, towards the mouth. This indicates that a portion of the nutrients which are entering the river may be settling out.

Among the Serpentine, Nicomekl, and Little Campbell Rivers, nutrients in sediments were similar (see Section 2.4.3.2).

4.4.4 OXYGEN AND OXYGEN-CONSUMING MATERIALS

The lowest recorded dissolved oxygen value on the Nicomekl River was 0.8 mg/L at Site 1100003 (Table 19), near the mouth. Other low minimum values were near the mouth: 1.3 mg/L at Site 0300060, 2.5 mg/L at Site 1100002, and 5.4 mg/L at Site 1100005. Minimum values were higher further upstream near the headwaters. Criteria for the protection of salmonids(83) are a minimum dissolved oxygen value of 8.0 mg/L to provide for no impairment and 6 mg/L which could cause slight impairment.

Percent saturation values became more variable near the mouth. At Site 1100003, values ranged from 8.8% to 263.8%. Such wide ranges in percent saturation will cause extreme stress in aquatic life. They are likely associated with high nutrient and algal growth levels which have arisen due to agricultural inputs.

Near the mouth of the Nicomekl River, between May and August of 1979, values ranged from 2.5 mg/L to 6.7 mg/L at Site 1100002, while 5.2 mg/L was recorded at Site 1100003 and 5.4 mg/L at Site 1100005. Between September and November, values ranged from 4.0 mg/L to 4.3 mg/L at Site 1100002, and from 0.8 mg/L to 1.9 mg/L at Site 1100003. A value of 1.3 mg/L was recorded in November 1982 at Site 0300060. Salmonid migration takes place from August to November, with spawning from November to May. Thus, low oxygen levels existed at critical times of the year.

Fish spawning (Figure 5) occurs in the upper reaches of the Nicomekl River near Sites 0300062 and 1100007. At these sites, dissolved oxygen levels have ranged from 7.8 to 14.1 mg/L and 8.7 to 13.0 mg/L, respectively. These levels provide virtually no impairment to salmonids. Since spawning occurs after about November 1, there is likely sufficient dissolved oxygen to meet spawning requirements.

The lowest dissolved oxygen level in Murray Creek was 6.0 mg/L at Site 1100022 (Table 22). In Anderson Creek, the lowest value was 8.25 mg/L at Site 1100017 (Table 21). Percent saturation values ranged from 62.8% at Site 1100022 to 123.5% at Site 0300064 in Murray Creek. In Anderson Creek, values ranged from 76.4% to 159.3% at Site 1100017. Both the dissolved oxygen and percent saturation values are not as variable in Anderson and Murray Creeks as in the Nicomkel River.

Salmonids in Murray Creek were subjected to from slight to no impairment at all times (≥6.0 mg/L)(83), while those in Anderson Creek were not affected (≥8.0 mg/L)(83). As well, they were not subjected to the same degree of stress as was aquatic life in the Nicomekl River where percent saturation values fluctuated more widely. This is likely due to the fact that most inputs of nutrients and oxygen-demanding materials from all the water bodies are concentrated nearer the mouth of the Nicomekl River, and thus this is where the greatest impact from lack of oxygen occurs.

There are therefore periods of real concern with dissolved oxygen levels in the Nicomekl River. Any proposed objective must recognize this, and allow for improvements to be made in the watershed which will be reflected in higher dissolved oxygen concentrations in the future.

Therefore, staged provisional objectives are proposed for the minimum dissolved oxygen concentration in the Nicomekl River. To protect salmonids initially, the minimum dissolved oxygen concentration should not be less than 6.0 mg/L. Once this minimum is consistently met as it appears to be in Anderson and Murray Creeks, the objective for a minimum value should be increased to 8.0 mg/L which is also the proposed objective for Anderson and Murray Creeks. In addition, between November and May in spawning areas of the Nicomekl River, Murray and Anderson Creeks, the minimum dissolved oxygen concentration should not be less than 11.0 mg/L when larvae or alevin are present. These objectives apply to insitu measurements or discrete samples taken outside the initial dilution zones of effluents, as described in Section 2.4.4.

There are no permitted point-source discharges within this drainage basin which impact dissolved oxygen values. Remedial activities would therefore relate to non-point sources. Remedial action to maintain oxygen concentrations within a suitable range for the protection of aquatic life is not presently being undertaken(40). However, results of aeration studies on the Serpentine River may also be applicable to the Nicomekl River system.

4.4.5 BACTERIOLOGICAL QUALITY

Fecal coliform data within the Nicomekl River system were collected from four sites (1100006, 1100007, 1100017, 1100022) in April 1979, five different sites (0300060, 0300061, 0300062, 0300063, 0300064) between 1974 and 1982, and at one site (1100001) in March 1976. Values collected in March 1976 ranged from 130 to 490 MPN/100 mL (mean: 305 MPN/100 mL, median: 330 MPN/ 100 mL) at Site 1100001 near the mouth of the river.

Fecal coliform data were also analyzed for Sites 0300060, 0300061, 0300062, 0300063, and 0300064 between 1974 and 1982. These data indicate variable values at Site 0300062 near the headwaters, ranging from 207 to >24 000 MPN/100 mL. Values then decreased downstream to Site 0300060, near the mouth of the Nicomekl River where the range was <2 to 9200 MPN/100 mL. The main water uses on the Nicomekl River, Anderson Creek, and Murray Creek are irrigation, and livestock watering. The B.C. Ministry of Health does not approve of the use of these waters as a drinking water supply. The criteria for confined livestock limit the 90th percentile of fecal coliforms to 10 MPN/100 mL for water used after disinfection only(7,30). The 90th percentile of fecal coliform data, collected over a ten-year period at Sites 0300060 (2 400 MPN/100 mL), 0300061 (2 400 MPN/ 100 mL), 0300062 (7 680 MPN/ 100 mL) on the Nicomekl River and for a four-year period at Sites 0300063 (880 MPN/100 mL) and 0300064 (1 540 MPN/ 100 mL) on Anderson Creek and Murray Creek, respectively, exceeded this criterion level and complete water treatment plus disinfection would be needed before use. A long-term objective of reducing fecal coliform concentrations to a geometric mean below 200 MPN/100 mL to protect livestock watering is proposed. Geometric mean values are to be calculated from a minimum of five weekly samples collected over a 30-day period. Drinking water license holders should be advised that, at present, complete water treatment may be necessary for Nicomekl River, Anderson Creek, and Murray Creek water prior to use and that the B.C. Ministry of Health does not approve of the use of these waters for human consumption. Further monitoring for fecal coliforms and streptococci should be conducted to determine the present levels and sources of fecal contamination in the basin. This will indicate the feasibility of attaining the long-term objective. This objective applies to areas outside initial dilution zones of effluent as outlined in Section 2.4.1.

The B.C. criterion for general irrigation (geometric mean value of 1000 MPN/ 100 mL)(30) was exceeded at Site 0300062 between May and August (1730 MPN/100 mL), and between September and December (1347 MPN/ 100 mL); and at Site 0300061, downstream from the Township of Langley, between September and December (1056 MPN/100 mL). This criterion is similar to the approved water quality objectives for the Fraser River(82). There is a more restrictive B.C. criterion (geometric mean of ≤200 MPN/ 100 mL)(30) for irrigation of crops eaten raw. There are twelve permitted irrigation withdrawals in the upper reach of the river, from the headwaters of the Nicomekl River to Site 0300061. Therefore, it is proposed that a provisional objective should be established for fecal coliforms in the Nicomekl River basin. In the long-term, the geometric mean fecal coliform values should remain below 200 MPN/ 100 mL at all times. In the short-term, the geometric mean should be ≤1000 MPN/100 mL and the maximum not greater than 4000 MPN/ 100 mL in the April to October period. These objectives apply to discrete samples or the mean of discrete samples taken anywhere in the Nicomekl River basin outside the initial dilution zones of effluents, described in Section 2.4.1.

4.4.6 SOLIDS

The maximum recorded suspended solids concentration in the Nicomekl River was 87 mg/L at Site 0300062 (Table 19). In Anderson Creek the maximum value was 42 mg/L at Site 0300063 (Table 21), while it was 55 mg/L at Site 0300064 in Murray Creek (Table 22). Such values would provide a moderate level of protection to aquatic life(26). The most restrictive criteria to protect aquatic life are that the induced suspended solids concentration should not exceed 10 mg/L when background levels are less than 100 mg/L, and should not be more than 10% of background when background is greater than 100 mg/L(14).

These criteria are proposed as the provisional water quality objective for suspended solids in the Nicomekl River, and Anderson and Murray Creeks. The objective is that induced suspended solids concentrations should not exceed 10 mg/L when background levels are less than 100 mg/L, nor should be more than 10% of background when background is greater than 100 mg/L. These objectives apply to discrete samples collected outside the initial dilution zones of effluents as described in Section 2.4.1.

In addition, to protect salmonid spawning areas, there should be no significant (95% confidence level) induced benthic sedimentation on the basis of accumulation by weight for particles <3 mm.

Maximum turbidity values were measured at Site 0300062 in the Nicomekl River (56 NTU), at Site 1100022 in Murray Creek (88 NTU), and at Site 0300063 in Anderson Creek (11 NTU). Since arithmetic mean values at all sites in the Nicomekl River and Murray Creek exceeded the water quality criterion of 5 NTU (maximum) for drinking water supplies, filtration or equivalent would be required in most cases prior to drinking. In Anderson Creek, the values met this criterion in most of the samples (17 of 19).

Higher turbidity values were recorded between November and May in the Nicomekl River. These increases are likely due to increased stormwater runoff during this time of the year.

B. C. criteria exist for induced turbidity(14). These will be used as the proposed water quality objectives for turbidity. The objective is that induced levels should not exceed 5 NTU when background is less than 50 NTU nor should they increase by more than 10% when background is greater than 50 NTU. The objective applies to the Nicomekl River, Anderson Creek, and Murray Creek.

Dissolved solids, as indicated by their direct measurement or by measuring specific conductivity, can reach high values due to saltwater intrusion as far upstream in the Nicomekl River as Site 1100006. At this site, and further upstream, all values have been less than 500 mg/L (Table 19). Such was also the case for Anderson Creek (Table 21) and Murray Creek (Table 22). Working water quality criteria are 500 mg/L for drinking water supplies(7), 1000 mg/L for livestock watering(76), and from 500 to 3500 mg/L for irrigation, depending on the soil and crop(76). Thus there are times in the lower reaches of the Nicomekl when dissolved solids exceed these criteria and the water may not be suitable for these uses.

4.5 RECOMMENDED MONITORING

Several calculations in this report have predicted the maximum potential impact of agriculture. A site-specific study should be designed for sites near the headwaters and near the mouth of the Nicomekl River to determine the local impact of agricultural operations. The exact study design should be considered in the future. As well, a site-specific study should be undertaken near Langley to determine stormwater impacts. The exact study design should also be considered in the future.

Several water quality objectives have been proposed. To determine whether these are being achieved, it is recommended that a minimum of two sites on the Nicomekl River, one upstream from Langley and one near the mouth, as well as a site on each of Anderson Creek and Murray Creek, be selected. Additional sampling sites should be used when the objectives are exceeded. A minimum sampling frequency of five samples in a 30-day period is recommended. Samples should be analyzed for pH, dissolved oxygen, temperature, specific conductivity, ammonia, nitrite, nitrate, dissolved orthophosphorus, total phosphorus, dissolved and suspended solids, fecal coliforms, fecal streptococci, turbidity, periphyton chlorophyll-a, and dissolved and total copper, iron, manganese, and lead. However, resources and other regional priorities will determine the exact program.

4.6 CONCLUSIONS

Operations discharging effluents within the Nicomekl drainage basin include two landfills, one cooling water discharge, eight soil disposal systems, and a bulk petroleum storage plant. Remedial activities (installation of a leachate collection system) to improve water quality in a tributary to the Nicomekl River have been initiated at the landfill operated by the Township of Langley (PR 1898). The leachate collection system is expected to discharge to a sewer system in the future. Mansonville Plastics Ltd. may discharge uncontaminated cooling water to the Nicomekl River. It has been determined that the dilution rate is sufficient within the Nicomekl River for effluent discharged at the permitted temperature (<32°C) not to impact the water quality. However, it is not known what actual effect this effluent has on the Nicomekl River as no data on actual temperatures of the discharged cooling water have been recorded. Several soil disposal systems and one landfill operation either discharged to areas at a sufficient distance from the river or have the effluent trucked to a local municipal sewage treatment facility in Langley. The largest impact on the Nicomekl River system is likely from agricultural operations.

The pH of water in the basin was naturally high, and it was well-buffered to acidic inputs. Some higher metal values were recorded, but these were likely naturally occurring. High lead values may originate from stormwater discharges. Ammonia and nitrite values were below criteria to protect aquatic life. High levels of phosphorus and the consequent heavy algal growth, photosynthesis, respiration, and decay are believed to be responsible for low dissolved oxygen levels and wide ranges of percent saturation values. These are not as pronounced in the Upper Nicomekl River and in Murray or Anderson Creeks as they are in the lower Nicomekl River. High fecal coliform levels require a high level of treatment of water prior to human and livestock consumption. High dissolved solids near the mouth of the Nicomekl River reflect saltwater intrusion.

5. BOUNDARY BAY

5.1 OCEANOGRAPHY

Boundary Bay, including its northeasterly extension of Mud Bay and the southeast section called Semiahmoo Bay, is located on the south side of the Fraser-Delta area approximately 19 km south from the City of Vancouver. It is 15 km long and 4 km wide, covering an area of 6087 hectares. The Bay is rectangular in shape and faces southeast onto the southern Strait of Georgia (Figure 4).

Weir (1963)(44) used six automatic tide gauges to determine vertical movement within Boundary Bay. It was observed that the tides enter from the south and are more concentrated on the eastern side during flood tide, while being more concentrated on the western side during ebb tide.

Water flow from the Blaine area of Washington State into Boundary Bay occurred on a daily basis from January to June and in October and on a semi-daily basis for the remainder of the year(43,44). This indicates that water quality within Boundary Bay may be influenced by Puget Sound water, entering during flood tides from the Blaine area. It can also be influenced by outflows from the Serpentine River, Nicomekl River, and Little Campbell Rivers. The frequency at which water flowed north from Boundary Bay to the Fraser River delta was equally distributed between daily and semi-daily occurrences during 1985(43,44).

5.2 WATER USES

Boundary Bay and Mud Bay sustain a crab fishery (Table 25), a herring herring fishery (Table 26), and a salmonid sports fishery. The oyster fishery has been closed to commercial and recreational harvesting since 1963 due to fecal contamination and the presence of an oyster parasite (Japanese Oyster drill *Oceanebea japonica*). Clams are still taken illegally.

Recreational usage in this area consists of swimming, boating, bird watching, and horseback riding along the dyke(49). Swimming occurs at Boundary Bay Beach, Centennial Beach, Crescent Beach, and near White Rock (Figure 4).

5.3 WASTE DISCHARGES

Swain and Alexander(3) described the sewage discharge facilities operating in Boundary Bay. Sewage pump stations in White Rock were connected to the Greater Vancouver Sewage and Drainage District (GVS & DD) in 1977. The Semiahmoo Indian Band reserve was unsewered in 1977 with possible septic tank seepage occurring at three residences; however, it is doubtful if the seepage could exert a significant impact on the water quality at Semiahmoo Bay(3). This area has not been sewered since that time.

There are no permits to discharge wastes, pursuant to the Waste Management Act, into Boundary Bay or Mud Bay.

Within the Fraser River Estuary, holding tanks with a capacity of less than 22.7 m^3/d have been approved as a method of sewage treatment for houseboat communities and marinas. There are no houseboat communities in Mud Bay or Boundary Bay. Sewage from a marina near Crescent Beach is sent by way of a sanitary sewer to the Annacis Island Sewage Treatment Facility. A marina at the mouth of the Nicomekl River also discharges sewage to the Annacis Island Sewage Treatment Facility.

In summary, point source waste discharges do not enter Mud Bay or Boundary Bay, and therefore do not have a negative impact on water quality. However, non-point sources containing contaminants continue to be discharged into Boundary Bay through land-drainage pump stations. The locations of these are indicated by P1 to P5 on Figure 4. The pump stations are required to lift drainage water, which accumulates in ditches, over the dykes and into the Bay. The following discussion has been extracted from Swain and Alexander(3).

The five land-drainage pump stations were sampled during November and December of 1977. These pump stations drain predominantly agricultural-type land. Bacteriological results indicate that the lowest total and fecal coliform values occurred at P-2 (median values 270 MPN/100 mL and 33 MPN/100 mL, respectively) and the highest at P-3 (median values 5 400 MPN/100 mL and 140 MPN/100 mL, respectively). These results suggest that the pump discharges were not significant sources of fecal contamination, but this would depend on the volumes pumped. Local contamination can possibly be expected.

The following median nutrient values were reported in the drainage water: orthophosphorus (P), 0.17 mg/L; total phosphorus, 0.25 mg/L; nitrite-N, 0.018 mg/L; nitrate-N, 1.4 mg/L; and ammonia-N, 0.44 mg/L(3).

Samples of land-drainage water were also collected at the same time to determine 96-hour LC50 values from static bioassays, using rainbow trout as the test species. Seven tests were performed on the drainage water from the five pump stations. These tests indicated that the waters were not acutely toxic.

Sediments adjacent to the outfalls from the drainage pump stations were analyzed at the same time for hexachlorobenzene and the polychlorinated biphenyl, Arochlor 1 260. All samples analyzed had less than one part per billion (ppb) hexachlorobenzene. However, significant concentrations of Aroclor 1 260 were found at P-3 and P-4. The concentrations at a distance of 4.6 metres west of the outfall were 1 200 ppb at P-3 and 3 800 ppb at P-4, compared to 31 ppb at background stations. Subsequent sampling by the Environmental Protection Service at these locations did not reveal high levels of polychlorinated biphenyls.

5.4 WATER QUALITY AND PROPOSED PROVISIONAL WATER QUALITY OBJECTIVES

Swain and Alexander(3) examined water quality data at Sites 0300070 and 0300071 within Boundary Bay for a seven-year period between 1972 and 1979. Three samples, two in 1980 and one in 1982, were collected and analyzed after this period. These data are in Table 24. The data from Swain and Alexander(3) and Table 24 are discussed in the following sections.

5.4.1 pH AND BUFFERING CAPACITY

Values for pH, collected between 1973 and 1982, were relatively uniform in Boundary Bay. At Sites 0300070 and 0300071 these values ranged from 7.6 to 8.5 with a median of 8.0. All pH values reported for Sites 0300070 and 0300071 were within the criterion range for the protection of marine aquatic life (6.5 - 8.5)(31).

Median alkalinity values were about 115 mg/L at Site 0300071 and 100 mg/L at Site 0300070.

5.4.2 METALS

Total cadmium values were collected at both sites in July 1982. These values were similar (0.001 mg/L at Site 0300070 and 0.0015 mg/L at Site 0300071), but outside the historical ranges reported by Swain and Alexander(3) (0.0001 mg/L to 0.0005 mg/L at both sites). The working criteria for the protection of marine aquatic life (maximum value: 0.043 mg/L, 4-day mean value: 0.009 mg/L)(63) were not exceeded by total cadmium values at either site in Boundary Bay.

Total manganese values between 1974 and 1980 at Sites 0300070 and 0300071 ranged from 0.002 mg/L to 0.016 mg/L and between 0.003 mg/L to 0.015 mg/L, respectively. Dissolved manganese values for the period 1973 to 1977, ranged from 0.002 mg/L to 0.006 mg/L at Site 0300070 and from 0.002 mg/L to 0.008 mg/L at Site 0300071. All values were less than the criterion level for the protection of consumers of marine mollusks (0.1 mg/l)(81).

Total chromium values between 1972 and 1982 ranged from <0.005 mg/L to 0.022 mg/L at Site 0300070 and from <0.005 mg/L to 0.02 mg/L at Site 0300071. All values were less than the working criteria (4-day average value: 0.05 mg/L, maximum value: 1.1 mg/L) for the protection of marine aquatic life(47).

Total copper values ranged from <0.001 mg/L to 0.04 mg/L at Site 0300070 (period of record: 1972-1982) and from <0.001 mg/L to 0.007 mg/L (period of record: 1973-1982). B.C. criteria for total copper, in an estuarine or marine environment, for the protection of aquatic life are: 30-day average value 0.002 mg/L, maximum value 0.003 mg/L(66). Eleven of fifty-seven samples collected at Site 0300070 exceeded the maximum criterion. At Site 0300071, the maximum criterion was exceeded in nine of fifty samples collected over the period of record. It is not known if these copper levels are natural.

Total lead values ranged from <0.001 to 0.032 mg/L at Site 0300070 from 1972 to 1982 and from <0.001 mg/L to 0.007 mg/L at Site 0300071 from 1973 to 1982. The B.C. criterion for the protection of aquatic life in a marine or estuarine environment limits total lead values to a 30-day average value of 0.002 mg/L and a maximum value of 0.14 mg/L(84). The 30-day average criterion was not exceeded by the median value of all samples collected and the maximum criterion was never reached.

Total mercury values were measured between 1978 and 1982 at Sites 0300070 and 0300071 (values ranged from < 0.00005 mg/L to 0.00068 mg/L and from <0.00005 mg/L to 0.00083 mg/L, respectively). Dissolved mercury values, collected between 1973 and 1978, ranged from <0.00005 mg/L to 0.00025 mg/L at Site 0300070 and from <0.00005 mg/L to 0.00033 mg/L at Site 0300071. The working criteria for the protection of consumers of fish (0.0001 mg/L)(12) and the protection of aquatic life (0.0002 mg/L)(12) were exceeded in one (0.00083 mg/L) of twelve samples at Site 0300071 and in six (value range: 0.0001 mg/L - 0.00068 mg/L) of sixteen samples from Site 0300070. It is recommended that monitoring be conducted to determine the cause of these elevated values. Such monitoring would examine anthropogenic sources which may contribute mercury to this area and determine the frequency at which values greater than the criteria occur. It should include sampling of resident aquatic species to see if criteria for human consumption are achieved.

Nickel values at both sites were at or below the detection level of 0.01 mg/L.

Total zinc values at Site 0300070, for the period 1972 to 1982, ranged from <0.005 mg/L to 0.13 mg/L (twenty-six of fifty-seven samples were greater than the 0.005 mg/L detection level). At Site 0300071, for the period 1973 to 1982, total zinc values ranged from <0.005 mg/L to 0.05 mg/L (seventeen of forty-five values were greater than the 0.005 mg/L detection level). The working criteria for the protection of marine aquatic life limit total zinc values to a 30-day average value of 0.058 mg/L and a maximum value of 0.17 mg/L(68). The average criterion was exceeded in one (0.13 mg/L) of fifty-seven samples collected at Site 0300070, while all values at Site 0300071 were less than the average criterion.

High metal values occurred more frequently at Site 0300070 than at Site 0300071. This may be attributed to the proximity of the site to the City of White Rock, Blaine, and Drayton Harbour. Urban discharges, including stormwater runoff, may contribute to higher metal concentrations at this site.

5.4.3 NUTRIENTS

Total ammonia nitrogen values ranged from <0.01 mg/L to 0.09 mg/L at Site 0300070 between 1972 and 1980. At Site 0300071, between 1973 to 1980, total ammonia values ranged from <0.01 mg/L to 0.07 mg/L. All values were less than the B.C. criteria for marine aquatic life of 2.5 mg/L as a maximum value and <1.0 mg/L as an average value(69).

Nitrogen concentrations (nitrate-nitrogen, nitrite-nitrogen, and organic nitrogen) remained generally constant over the period of record at Sites 0300070 and 0300071 in Boundary Bay. Nitrate-nitrogen values at Site 0300071 were slightly higher than at Site 0300070 (value range at Site 0300070: <0.02 mg/L to 0.41 mg/L, mean: 0.15 mg/L; at Site 0300071: <0.02 mg/L to 0.57 mg/L, mean: 0.24 mg/L). One nitrite value of 0.079 mg/L was reported for Site 0300071 (Table 24). Although there are no B.C. criteria for nitrite to protect marine life, a B.C. criterion for freshwater of a maximum of 0.6 mg/L nitrite is to be used for water with a chloride concentration >10 mg/L. Since the waters of Boundary Bay have far in excess of 10 mg/L chloride, the single high nitrite value is not of concern.

Orthophosphorus values ranged from <0.003 mg/L to 0.077 mg/L (mean value: 0.04 mg/L) at Site 0300070 and from <0.003 mg/L to 0.088 mg/L (mean value: 0.04 mg/L) at Site 0300071 for the period 1973 to 1982. Total dissolved phosphorus values ranged from 0.014 mg/L to 0.076 mg/L (mean value:- 0.05 mg/L) at Site 0300070 and from 0.013 mg/L to 0.075 mg/L (mean value: 0.06 mg/L) at Site 0300071. Seasonally, values for orthophosphorus and total dissolved phosphorus decreased between May and September and increased between October and April.

5.4.4 OXYGEN AND OXYGEN-CONSUMING MATERIALS

Dissolved oxygen values ranged at Site 0300070 from 5.8 mg/L to 12.1 mg/L (mean: 9.0 mg/L) and at Site 0300071 from 6.3 mg/L to 14 mg/L (mean: 8.8 mg/L). These values became less variable in more recent times at both sites (value range for the period 1972-1975 at Site 0300070: 5.8 mg/L to 12.1 mg/L, for the period 1976-1982: 6.6 mg/L to 10.8 mg/L; value range for the period 1973-1975 at Site 0300071: 6.3 mg/L to 14 mg/L, for the period 1976-1980: 6.6 mg/L to 10.5 mg/L). The working marine criteria to provide moderate to high protection for non-anadromous fish species and anadromous species with salmonids are that dissolved oxygen levels should be from 6.75 mg/L to 8.75 mg/L and from 6.5 mg/L to 9.0 mg/L, respectively(10). At Site 0300070, the level fell below the minimum of

6.5 mg/L for a moderate level of protection only in one of fifty-five samples collected over a ten-year period. At Site 0300071, the level fell below the minimum value of 6.5 mg/L only in one of forty-five samples collected over a seven-year period. However, the mean dissolved oxygen levels in Boundary Bay were about the same as the minimum criteria for a high level of protection, suggesting that a high level of protection was achieved only about 50% of the time.

Since oxygen-consuming materials are entering the Bay from non-point discharges and through the tributaries, a provisional objective is proposed for dissolved oxygen. The objective is that the minimum dissolved oxygen level should not be less than 6.5 mg/L. A second long-term objective of a minimum of 9.0 mg/L is also proposed. The objectives apply to in-situ measurements or discrete samples in all areas of the Bay, except in initial dilution zones of effluents. These excluded initial dilution zones in the Bay are described as extending 100 m horizontally in all directions, but not to exceed 25% of the width of the waterbody.

5.4.5 SOLIDS

Suspended solids values at both sites were low, with mean values of about 6 mg/L and a maximum of 29 mg/L at Site 0300070 for the period 1972-1982. At Site 0300071 for the period 1973 to 1982, the maximum value was 31 mg/L. Dissolved solids values ranged from 24 500 mg/L to 33 200 mg/L (mean value: 30 561 mg/L) at Site 0300070 for the period 1974 to 1978 and from 25 200 mg/L to 33 600 mg/L (mean value: 30 836 mg/L) at Site 0300071 for the period 1974 to 1978. These values indicate that suspended solids values and dissolved solids values were relatively uniform throughout Boundary Bay.

Turbidity values ranged at Site 0300070 from 0.4 NTU to 6.2 NTU (mean value: 1.45 NTU) and from 0.4 NTU to 8.4 NTU (mean value: 1.65 NTU) at Site 0300071.

Water quality objectives for suspended solids and turbidity are proposed for the protection of aquatic life in Boundary Bay. Induced turbidity values are to be less than 5 NTU while induced non-filterable residue values are to be less than 10 mg/L when background levels are less than 100 mg/L suspended solids or 50 NTU turbidity. If background levels exceed 100 mg/L suspended solids or 50 NTU turbidity, induced levels should not increase by more than 10% of background. These objectives apply in the Bay, except in initial dilution zones of effluents, described in Section 5.4.4.

5.4.6 BACTERIOLOGICAL QUALITY

Fecal coliform values, collected between 1973 and 1982, ranged from <2 MPN/100 mL to 790 MPN/100 mL at Site 0300071 and from <2 MPN/100 mL to 130 MPN/100 mL at Site 0300070. At Site 0300070, five of twenty-eight samples collected were greater than the detection levels (<2 MPN/100 mL, <20 MPN/100 mL). The detectable values ranged from 2 MPN/100 mL to 130 MPN/100 mL with a median value of 5 MPN/100 mL and 90th percentile value of 54 MPN/100 mL. Sixteen of twenty-six samples collected at Site 0300071 were less than the detection levels of 2 MPN/100 mL and 20 MPN/100 mL. In the remaining ten samples fecal coliform values ranged from 2 MPN/100 mL to 790 MPN/100 with a median value of 5 MPN/100 mL and 90th percentile value of 23 MPN/100 mL. Only one of fifty-four values exceeded the recreation criterion of 200 MPN/100 mL(70).

Kay(49) conducted a sanitary survey of Boundary Bay, Mud Bay, and Crescent Beach in 1976 (Figure 4). This survey measured fecal coliform levels from thirty-three marine stations during the three-month period from March to May," a time when hydrographic and pollution conditions were not expected to be the worst"(49). Twenty of "33 marine stations met the shellfish growing water standard. Of the remaining 13 sampling stations which were classified as unacceptable, 7 exceeded the standard at the median level and 6 exceeded the standard at the 90th percentile level"(49). Values at individual stations had ranged from <2 to 540 MPN/100 mL, with median values from <2 to 205 MPN/100 mL and 90th percentile from <4 to

350 MPN/100 mL. Thus, it was recommended that the Bay should stay closed to shellfish harvesting. However, it may be feasible to use Boundary Bay for growing shellfish commercially if they are removed to "clean" water prior to harvesting. Exact timing of such activities would have to be carefully investigated.

Fecal coliform data collected by the Ministry of Health at eleven beach sites (Figure 4) for the period of June to August between 1979 and 1985 are reported in Table 27.

The criteria for recreational beaches limit fecal coliform values to a geometric mean of less than 200 MPN/100 mL and a 90th percentile of less than 400 MPN/100 mL(70). The 90th percentile for fecal coliforms at Sites 1 to 4 adjacent to the City of White Rock and Sites 10 and 11 adjacent to the City of Boundary Bay exceeded the 90th percentile criterion (values ranged from 460 MPN/100 mL to >2400 MPN/100 mL), while the geometric mean criterion was met except at Site 1 (if median values reflect geometric means).

Slightly higher values near the City of White Rock may be attributed to the discharge of water from the Little Campbell River, tidal movement (water from Drayton Harbour and Puget Sound on a daily or twice daily basis), or stormwater runoff from the City of White Rock. It is proposed that a provisional objective should be established for all beaches in Boundary Bay. The geometric mean fecal coliform value should be less than or equal to 200 MPN/100 mL and the 90th percentile should be less than or equal to 400 MPN/100 mL (April through October). In addition, a long-term objective is proposed year-round for fecal coliforms in Boundary Bay where shellfish harvesting potentially can occur. The objective is that the median fecal coliform value should not exceed 14 MPN/100 mL and the 90th percentile value should not exceed 43 MPN/100 mL. For both proposed objectives, a minimum of five weekly samples should be collected within a period of 30 days. The objectives apply to areas outside the initial dilution zones of effluents, described in Section 5.4.4.

Further monitoring of fecal coliforms and fecal streptococci should be conducted to determine the present levels and sources of fecal contamination in the basin. This would indicate the feasibility of attaining these objectives.

5.4.7 POLYCHLORINATED BIPHENYLS (PCBs)

PCBs can enter Boundary Bay through the Serpentine River, from Mahood Creek. Within the confines of the Bay, the immediate exposure of fish or most other aquatic life would be minimized. However, sediments carried to the Bay may settle, carrying PCBs. This can possibly be a concern to the invertebrate populations in the Bay. For this reason, a provisional objective is proposed for PCBs in sediments in Boundary Bay. The objective is that the maximum concentration in bottom surface sediments should not exceed 0.03 µg/g (dry-weight). The term PCBs applies to the sum of Arochlor 1242, 1254, and 1260. The average of at least three replicate samples taken from the same site should be used to check the objective, which does not apply in the initial dilution zones of effluents, described in Section 2.4.1.

5.4.8 CHLOROPHENOLS

Chlorophenols entered Boundary Bay through the Serpentine River, from Hyland Creek in March 1984. Maximum total chlorophenol concentrations were 22.9 µg/L four days after the spill, but these were reduced to <0.1 µg/L six days later. Within the confines of the Bay, the immediate exposure of fish or most other aquatic life was minimal. Sediments carried into the Bay had no measurable levels (<10 µg/L). Clam tissue concentrations dropped from a maximum of 108 µg/g to <10 µg/g two months after the spill. Since there is no risk of a future discharge of chlorophenols to Boundary Bay, an objective will not be proposed.

5.5 RECOMMENDED MONITORING

No additional routine monitoring is recommended for Boundary Bay or the Mud Bay area. However, bacteriological sampling should be expanded to include fecal streptococci. This would provide information to determine the levels and sources of fecal contamination within Boundary Bay and Mud Bay.

A monitoring program to assess the elevated fecal coliform values adjacent to the City of White Rock is recommended to determine coliform loadings from stormwater discharging to the beach area. The aim of such a program would be to recommend remedial procedures to reduce fecal coliform levels within the White Rock area.

A second monitoring program is recommended to determine which factors contribute to the elevated copper and mercury levels and the frequency at which these exceed the criteria for the protection of aquatic life. The program should include anthropogenic sources, including stormwater, within the Boundary Bay and Mud Bay basin and sources which are outside the basin, but impact upon the water quality of the basin. As well, resident species of aquatic life should be examined for mercury levels.

Sites and frequency of sampling for both programs should be determined in an independent study design.

5.6 CONCLUSIONS

There are no permits issued pursuant to the Waste Management Act for the discharge of effluent into Boundary Bay or Mud Bay.

Boundary Bay and Mud Bay are used as a migratory corridor by salmonids and sea birds, sustain a commercial crab industry and herring industry, and are used for recreational purposes (boating, bathing). Prior to 1962, shellfish harvesting took place. Clams are still taken illegally.

Water quality in Boundary Bay was generally consistent for the period of record.

No routine monitoring is recommended in addition to existing programs conducted by the Ministry of Health and the Ministry of Environment and Parks. Two special programs are recommended to address elevated fecal coliform values adjacent to White Rock and a few elevated metal values in Boundary Bay and Mud Bay.

Elevated metal values occurred more frequently at Site 0300070 than at Site 0300071. This may be attributed to the proximity of the site to the city of White Rock, Blaine and Drayton Harbours. Urban wastes, including stormwater runoff, may contribute to higher metal concentrations at this site.

Routine bacteriological monitoring should be expanded to include fecal streptococci. A program should also be initiated to determine sources of fecal contamination within the drainage area. This would include determining fecal loadings from the Serpentine, Nicomekl, and Little Campbell River drainage areas, possibly from Puget Sound and Drayton Harbour, and anthropogenic sources resulting in point and non-point discharges to Boundary Bay and Mud Bay.

REFERENCES

1. Fraser River Estuary Study, Water Quality. Summary Report of the Water Quality Work Group. Ministry of Environment. Victoria, B. C. December 1979.

2. Halstead, E.L. Nicomekl-Serpentine Basin Study, British Columbia. Fisheries and Environment Canada, Inland Waters Directorate. Scientific Series No. 94. Vancouver, B. C. 1978.

3. Swain, L.G. and L.J. Alexander. Fraser River Estuary Study, Water Quality. Boundary Bay. Ministry of Environment. Victoria, B. C. June 1981.

4. United States EPA. Quality Criteria for Water. Washington, D. C. July 1976. p.7.

5. McNeeley, R.N., V.P. Neimanis and L. Dwyer. Water Quality Source Book, A Guide to Water Quality Parameters. Environment Canada, Water Quality Branch. Ottawa, Canada. 1979. p.3.

6. Environment Canada. Guidelines to Surface Water Quality, Vol. 1, Inorganic Chemical Substances. Ottawa, Canada. (Series of Reports 1979 to 1983).

7. Health and Welfare Canada. Guidelines to Drinking Water Quality 1978. Supply and Services Canada. Hull, Quebec. 1979. p.55.

8. Pommen, L.W. The Effects on Water Quality of Explosives Uses in Surface Mining, Volume 1: Nitrogen Sources, Water Quality, and Prediction and Management of Impacts. B.C. Ministry of Environment, MOE Technical Report 4. Victoria, B. C. May 1983.

9. Nordin, R.N. Water Quality Criteria for Nutrients and Algae. Ministry of Environment. Victoria, B.C. 1985.

10. Davis, J.C. Minimal Dissolved Oxygen Requirements of Aquatic Life with Emphasis on Canadian Species: a Review. Journal of the Fisheries Research Board of Canada. Volume 32 (12). 1975.

11. Richards, H.M. Ministry of Health. Memo to R.J. Buchanan, Water Management Branch, May 20, 1983.

12. Environment Canada. Guidelines for Surface Water Quality, Volume 1, Inorganic Chemical Substances. Ottawa, Canada. (Series of Reports 1979 to 1983).

13. United States EPA. Quality Criteria for Water. Washington, D.C. July 1976. p.267.

14. Singleton, H.J. Water Quality Criteria for Particulate Matter. Ministry of Environment. Victoria, B.C. 1985.

15. Ministry of Environment, Waste Management Branch. Permit File for Permit PE 6026. 1980.

16. United States EPA. Quality Criteria for Water. Washington, D.C. July 1976. p.240.

17. Swain, L.G. Fraser River Estuary Study, Water Quality. Industrial Effluents. Ministry of Environment. Victoria, B. C. December 1980.

18. Personal Communication. Mr. P. Johnson, Ministry of Agriculture, Abbotsford, B.C. to Mr. G.B. Holms, Water Management Branch. April 1985.

19. United States EPA. Quality Criteria for Water. Washington, D. C. July 1976. p.225-227.

20. Pommen, L.W. Approved and Working Criteria for Water Quality. Ministry of Environment. Victoria, B. C. 1987.

21. Stancil, D.E. Fraser River Estuary Study, Water Quality, Aquatic Biota and Sediments. Ministry of Environment. Victoria, B. C. December 1980.

22. McKean, C.J.P. Sediment Core Data From B.C. Lakes. Ministry of Environment and Parks. Victoria, B. C. (Unpublished).

23. Squamish Estuary Management Plan. Air and Water Quality Work Group Final Report. Ministry of Environment. Victoria, B. C. February 1981.

24. Swain, L.G. Stormwater Monitoring of a Residential Catchment Area: Vancouver, B. C. Water Management Branch Internal Report. Victoria, B. C. June 1983.

25. Bourque, S. and G. Hebert. A Preliminary Assessment of Water Quality and Biota in the Serpentine and Nicomekl Rivers and Mahood Creek. 1974-1975. Department of Environment, Environmental Protection Service. Regional Program Report:82-17. Vancouver, B. C. December 1982.

26. National Academy of Science. Water Quality Criteria, 1972. Washington, D.C., 1972. p.16.

27. Churchland, L.M. Fraser River Estuary Study, Water Quality; Microbial Water Quality, 1970-1977. Vancouver, B. C. 1980.

28. Arber, J. Fish Inventory Serpentine and Nicomekl Drainage Basins. Ministry of Environment and Parks. Victoria, B. C. 1977. (Unpublished).

29. Forsberg, C., S.O. Ryding, A. Claesson and A. Forsberg. 1978. Water Chemical Analyses and/or Algal Assay? Sewage Effluent and Polluted Lake Water Studies. Mitt. Int. Ver. Theor. Angew. Limnol. 21:352-363.

30. Warrington, P.D. Water Quality Criteria for Microbiological Indicators. Ministry of Environment and Parks. Victoria, B. C. 1988.

31. United States EPA. Quality Criteria for Water. Washington, D. C. July 1976. p.178.

32. Wetzel, R.G. Limnology. Second Edition. Saunders College Publishing 1983.

33. Hirst, S.M., R.L. Truelson, B.C. Clark, C.A. Easthope. Impacts of Agricultural Land Drainage on the Fish and Wildlife Resources of the Serpentine and Nicomekl Watersheds, British Columbia. British Columbia Fish and Wildlife Branch, Ministry of Environment. Vancouver, B. C. Internal Report. September 1979.

34. National Academy of Sciences. Water Quality Criteria, 1972. Washington, D.C. 1972. p.332.

35. United States EPA. Quality Criteria for Water. Washington, D. C. July 1976. p.25.

36. Health and Welfare Canada. Guidelines for Canadian Drinking Water Quality. 1978. Supply and Services, Canada. Hull, Quebec. 1979. p.43.

37. Environment Canada. Guidelines for Surface Water Quality, Vol. 1. Inorganic Chemical Substances. Ottawa, Canada. (Series of Reports 1979 to 1983).

38. National Academy of Sciences. Water Quality Criteria, 1972. Washington, D.C. 1972. p.344.

39. United States EPA. Quality Criteria for Water. Washington, D. C. July 1976. p.188.

40. Personal Communication. Dr. R.N. Nordin, Biologist, Resource Quality Section, Water Management Branch, Ministry of Environment and Parks. An Aeration Project on the Serpentine and Nicomekl Rivers.

41. Schubert, N.D. A Biophysical Survey of 30 Lower Fraser Valley Streams. Fisheries and Oceans, Canadian Manuscript Report of Fisheries and Aquatic Sciences, 1644. New Westminster, B.C. January, 1982. p.74.

42. Washburne, R. Washburne's Tables. Weatherly Press. 1985.

43. Canadian Hydrographic Service. Current Atlas: Juan de Fuca Strait to Strait of Georgia. Fisheries and Oceans, Ministry of Supply and Services Canada, Ottawa, Ontario.

44. Weir, W. 1963. Boundary Bay Reclamation: Part III - Report on Current measurements and Tidal Analysis. Private Report of C.B.A. Engineering Ltd. Vancouver, B.C.

45. United States EPA. Draft Water Quality Criteria. Federal Register, Volume 49, No. 26. February 1984. p.4551-4554.

46. United States EPA. Quality Criteria for Water. Washington, D. C. July 1976. p.95.

47. United States EPA, Water Quality Criteria; Availability of Documents; Notice, Federal Register Part II. July 1985. p.30788-30789.

48. Fraser River Estuary Study. Recreation Report of the Recreation Work Group. Appendix A. p.A73-A-81. August, 1978.

49. Kay, B.M. Shellfish Growing Water Sanitary Survey of Boundary Bay, Mud Bay, and Crescent Beach, British Columbia. Pollution Abatement Branch, Environmental Protection Service, Pacific Region. Vancouver, B. C. Report No. EPS 5-PR-76-11. November, 1976.

50. Health and Welfare Canada. Guidelines for Canadian Drinking Water Quality, 1978. Supply and Services Canada. Hull, Quebec. 1979. p.32.

51. International Joint Commission. Report to the Great Lakes Science Advisory Board, Report of the Aquatic Ecosystem Objectives Committee. November 1981.

52. Health and Welfare Canada. Guidelines for Canadian Drinking Water Quality, 1978. Supply and Services Canada. Hull, Quebec. 1979.

53. Health and Welfare Canada. Guidelines for Canadian Drinking Water Quality, 1978. Supply and Services Canada, Hull, Quebec. 1979. p.54

54. Clark, M.J.R. A Compilation of Water Quality Criteria, Report No. 78-7. Pollution Control Branch, Ministry of Environment and Parks. Victoria, B. C.

55. Health and Welfare Canada. Guidelines for Canadian Drinking Water Quality, 1978. Supply and Services Canada. Hull, Quebec. 1979. p.46.

56. United States EPA. Quality Criteria for Water. Washington, D. C. July 1976. p.206.

57. National Academy of Sciences. Water Quality Criteria. 1972. Washington, D.C., 1972. p.335.

58. United States EPA. Quality Criteria for Water. Washington, D. C. July, 1976. p.225-227.

59. Health and Welfare Canada. Guidelines for Canadian Drinking water Quality, 1978. Supply and Services Canada. Hull, Quebec, 1979. p.23.

60. National Academy of Sciences. Water Quality Criteria. 1972. Washington, D.C. 1972. p.33.

61. Sigma Environmental Consultants Ltd. Summary of Water Quality Criteria For Salmonid Hatcheries. Department of Fisheries and Oceans, Environment Canada. October 1983.

62. Canadian Council of Resource and Environment Ministers. Canadian Water Quality Guidelines. Ottawa, Canada. March 1987.

63. United States EPA. Ambient Water Quality for Cadmium. EPA 440/5-84-032; NTIS Number PB 85-227031. 1985.

64. United States EPA. Ambient Water Quality for Mercury: Consumers of fish. EPA 440/5-84-026; NTIS Number PB 85-227452. 1985.

65. United States EPA. Protection of Aquatic Life, EPA 440/5-84-026; NTIS Number PB 85-227452. 1985.

66. Singleton, H. Water Quality Criteria for Copper. Ministry of Environment and Parks. Victoria, B.C. 1987.

67. United States EPA. Federal Register: Water Quality Criteria; Availability of Documents; Notice Vol. 50 No 145, p.30791-30793. 1985.

68. United States EPA. Ambient Water Quality Criteria. Environmental Protection Agency, Criteria and Standards Division. Washington, D.C. 1980.

69. Nordin, R.N. and Pommen, L.W. Water Quality Criteria for Nitrogen. Ministry of Environment and Parks. Victoria, B.C. November 1986.

70. Richards, H.M. Ministry of Health. Memo to Dr. R.J. Buchanan, Water Management Branch, May 20, 1983.

71. United States EPA. Quality Criteria for Water. Washington, D. C. July 1976. p.206.

72. American Fisheries Society. A Review of the EPA Red Book: Quality Criteria for Water. Bethesda, Maryland. April 1979. p.121-125.

73. Personal Communication. Brian Bietz, Department of Fisheries and Oceans. New Westminster, B. C. Timing Specifications of Salmonid Spawning and Rearing in the Serpentine, Nicomekl, Little Campbell River Systems.

74. Clark, M.J.R. A Compilation of Water Quality Criteria, Report No. 78-7. Ministry of Environment and Parks. Victoria, B. C. 1978.

75. Canviro Consultants Ltd. 1985. Review of PCB Occurrence, Human Exposure and Health Effects. Kitchener, Ontario. (Prepared for Ontario Ministry of the Environment).

76. Canadian Council of Resource and Environment Ministers. Canadian Water Quality Guidelines. Ottawa, Canada. March, 1987.

77. American Fisheries Society. A Review of the EPA Red Book: Quality Criteria for Water. Bethesda, Maryland. 1979.

78. Bangay, G. E. Livestock and Poultry Wastes in the Great Lakes Basin. Environmental Concerns and Management Issues. Environment Canada Inland Waters Directorate, Ontario Region, Water Planning and Management Branch, Burlington, Ontario. 1976. Appendix 3.

79. Census Canada 1981.

80. Carelton, J. and S. Ashcroft. Surrey. Community Profile, for the Municipality of Surrey. July 1986.

81. United States EPA. Quality Criteria for Water, 1986. EPA 440/5-86-001. Washington, D. C.

82. Swain, L.G. and G. B. Holms. Water Quality Assessment and Objectives, Fraser-Delta Area, Fraser River Sub-basin From Kanaka Creek to the Mouth. Ministry of Environment. Victoria, B. C. 1985.

83. United States EPA. Ambient Water Quality Criteria for Dissolved Oxygen. Criteria and Standards Division. Washington, D. C. EPA 440/5-86-003.

84. Nagpal, N.K. Water Quality Criteria for Lead, Ministry of Environment and Parks, Victoria, B. C. 1987.

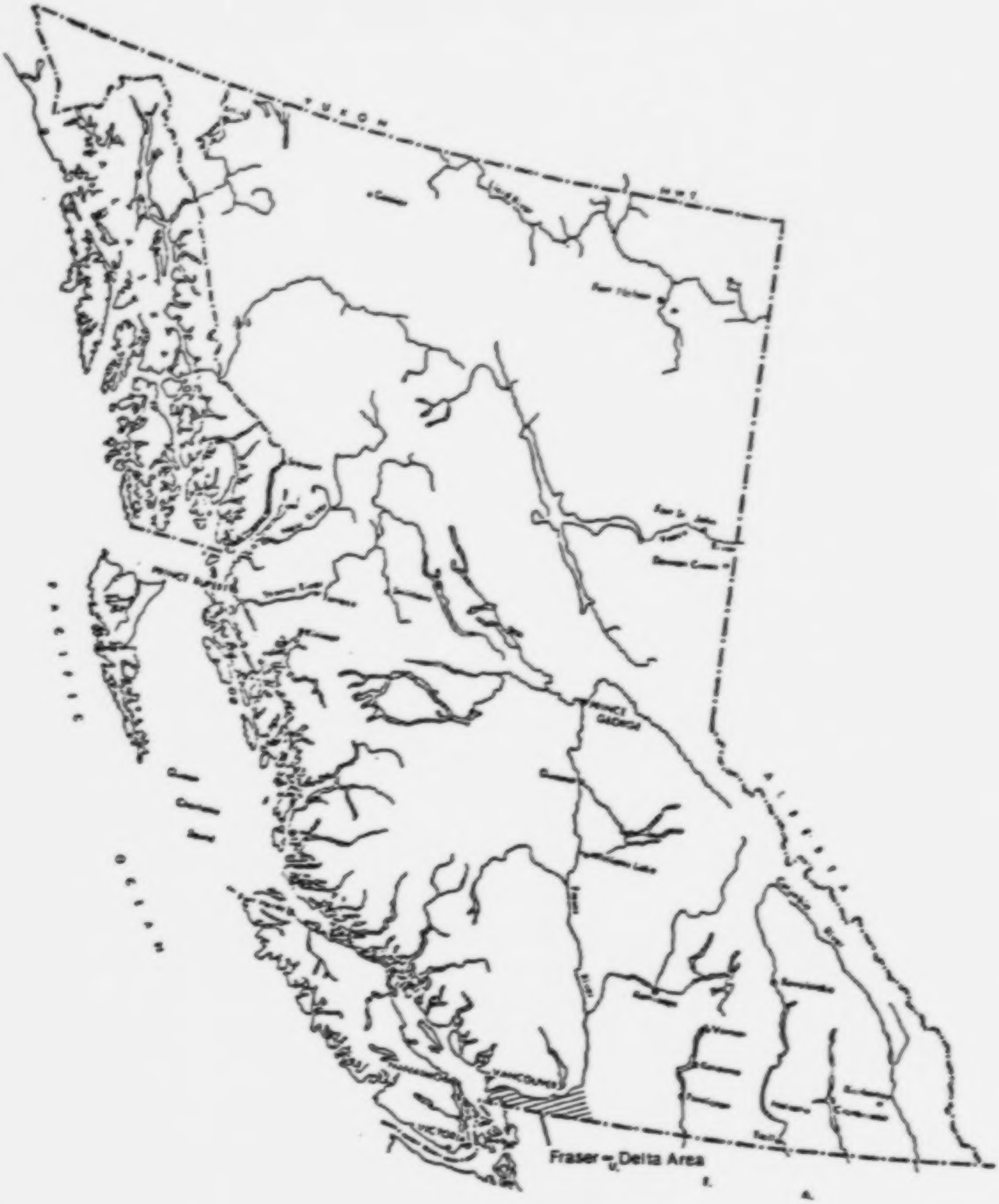

YUKON
N.W.T.
PACIFIC OCEAN
PRINCE GEORGE
ALBERTA
VANCOUVER
VICTORIA
Fraser Delta Area
U. S. A.

Figure 1. Location Map : FRASER -DELTA AREA

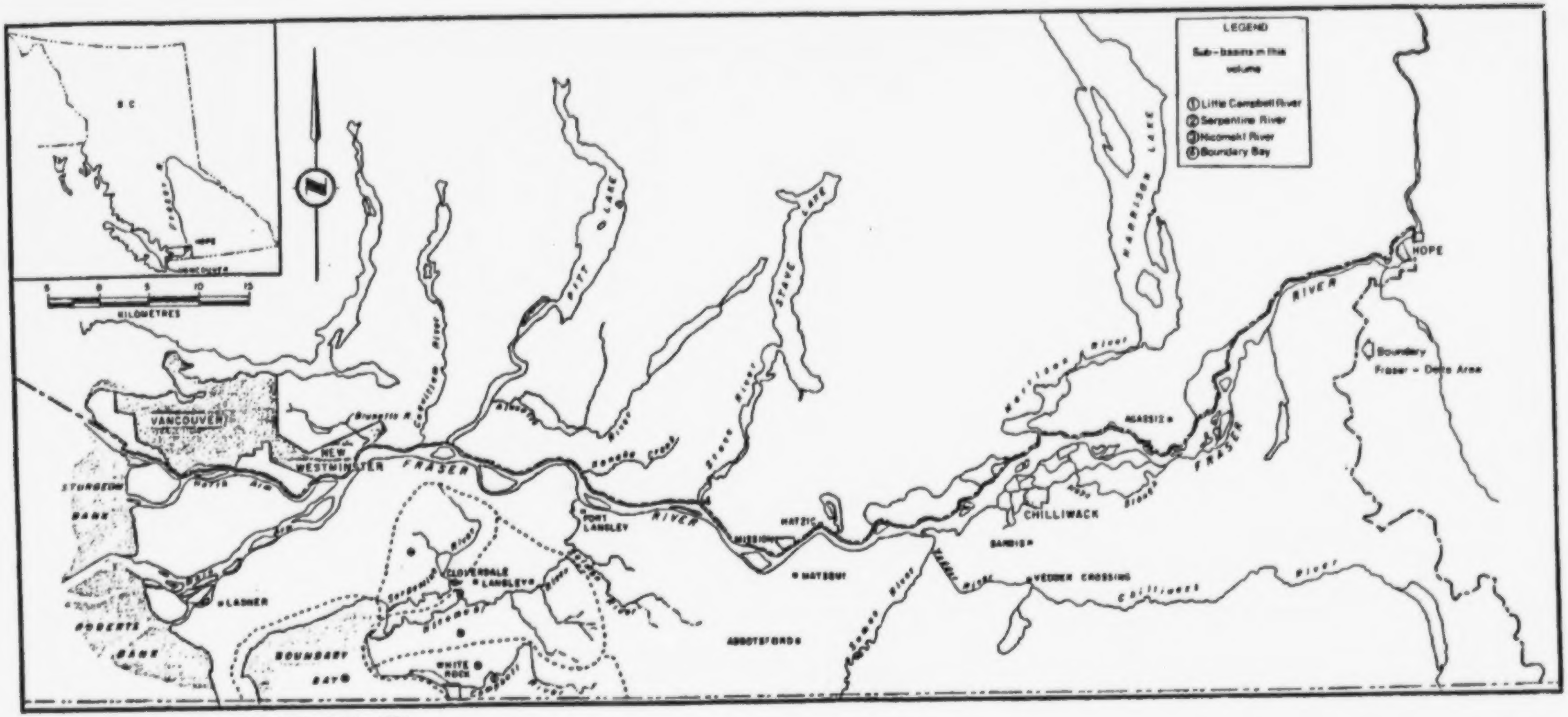

LEGEND
Sub-basins in this volume
① Little Campbell River
② Serpentine River
③ Nicomekl River
④ Boundary Bay
B.C.
HOPE
VANCOUVER
KILOMETRES
5
0
5
10
15
VANCOUVER
NEW WESTMINSTER
FRASER
RIVER
North Arm
STURGEON BANK
ROBERTS BANK
LADNER
BOUNDARY BAY
WHITE ROCK
CLOVERDALE
LANGLEY
Serpentine River
Nicomekl
Campbell River
Brunette R.
Coquitlam River
Alouette River
Kanaka Creek
PITT LAKE
STAVE LAKE
Stave River
PORT LANGLEY
Salmon River
MISSION
HATZIC
MATSQUI
ABBOTSFORD
Sumas River
Vedder River
VEDDER CROSSING
SARDIS
CHILLIWACK
Hope Slough
Chilliwack River
AGASSIZ
Harrison River
HARRISON LAKE
FRASER
RIVER
HOPE
Boundary Fraser - Delta Area

FIGURE 2 SUB-BASINS IN THE FRASER-DELTA AREA

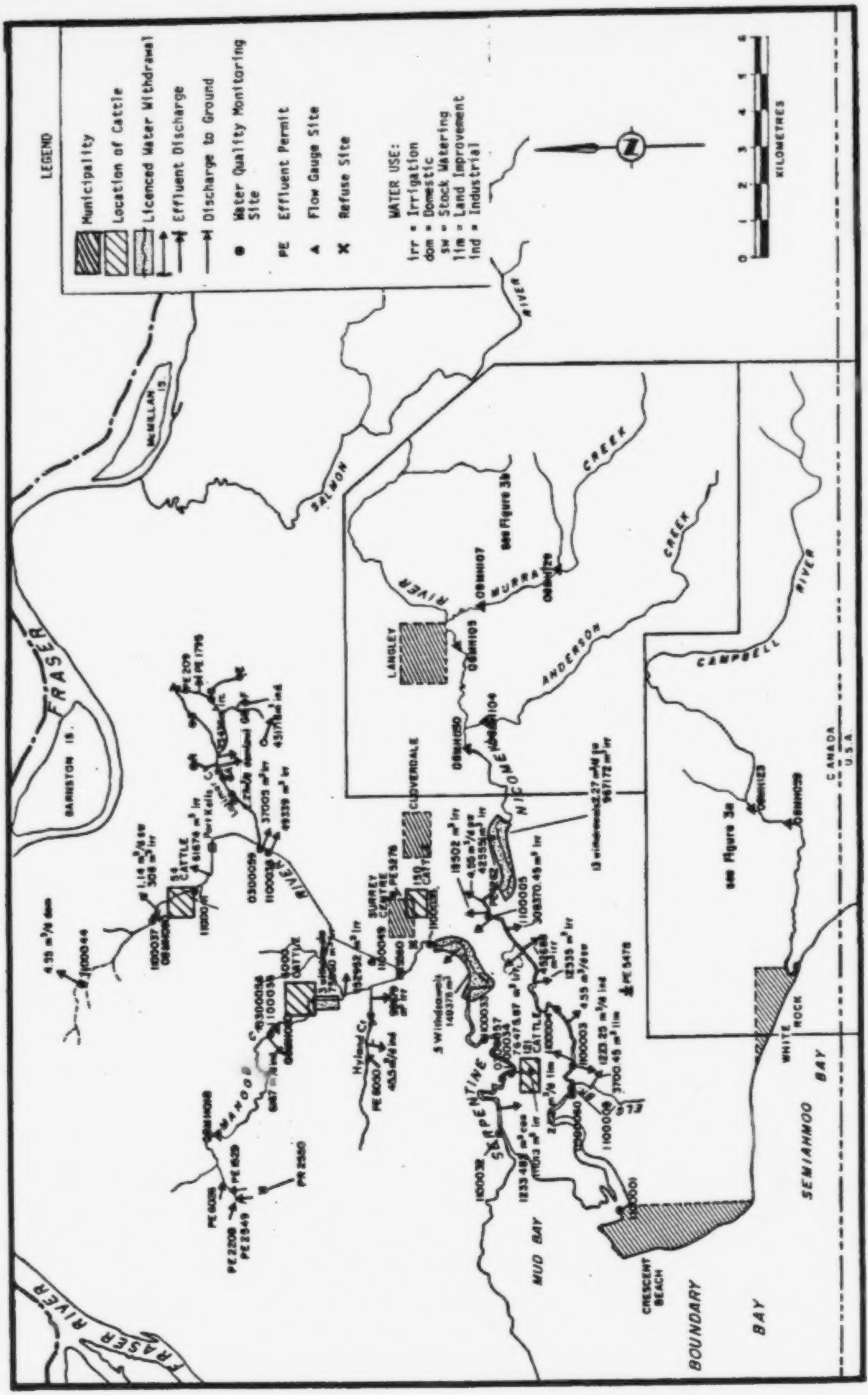

LEGEND
Municipality
Location of Cattle
Licenced Water Withdrawal
Effluent Discharge
Discharge to Ground
Water Quality Monitoring Site
PE Effluent Permit
Flow Gauge Site
Refuse Site
WATER USE:
irr = Irrigation
dom = Domestic
sw = Stock Watering
lim = Land Improvement
ind = Industrial
KILOMETRES
0
1
2
3
4
5
6
FRASER RIVER
FRASER
BARNSTON IS.
McMILLAN IS.
SALMON RIVER
LANGLEY
CLOVERDALE
SURREY CENTRE
NICOMEKL
SERPENTINE
ANDERSON CREEK
MURRAY CREEK
CAMPBELL RIVER
WHITE ROCK
CRESCENT BEACH
MUD BAY
BOUNDARY BAY
SEMIAHMOO BAY
CANADA
U.S.A.
see Figure 3a
see Figure 3b
CATTLE

Figure 3: Location of Waste Discharges, Water Quality Monitoring Sites, Flow Gauging Sites and Licenced Water Withdrawals, Boundary Bay and its Tributaries.

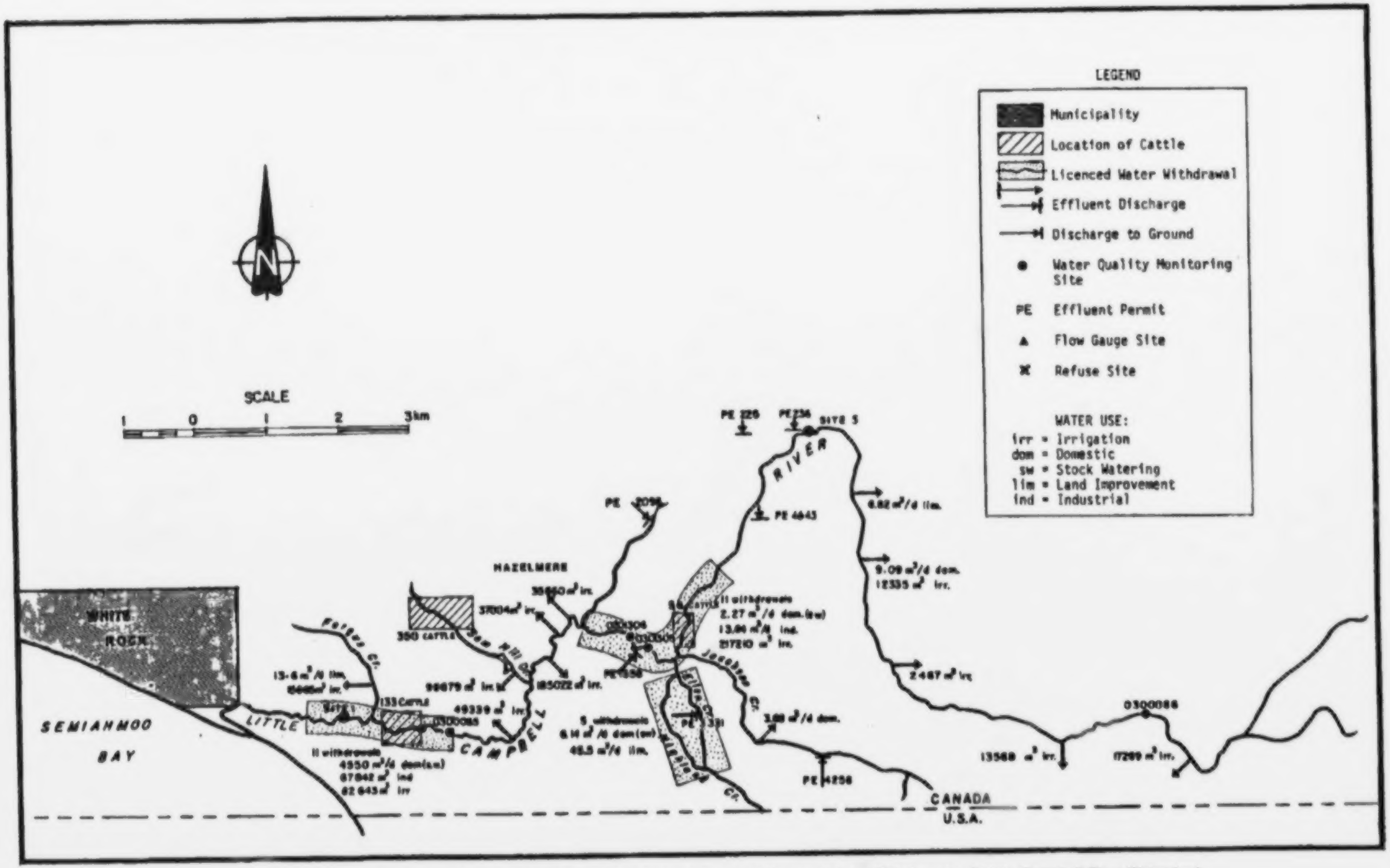

LEGEND
Municipality
Location of Cattle
Licenced Water Withdrawal
Effluent Discharge
Discharge to Ground
Water Quality Monitoring Site
PE Effluent Permit
Flow Gauge Site
Refuse Site
WATER USE:
irr = Irrigation
dom = Domestic
sw = Stock Watering
lim = Land Improvement
ind = Industrial
SCALE
1
0
1
2
3km
N
WHITE ROCK
SEMIAHMOO BAY
LITTLE
CAMPBELL
RIVER
HAZELMERE
Fergus Cr.
Bear Hill Cr.
Jacobsen Cr.
Ellis Cr.
Highland Cr.
13·6 m³/d lim.
350 cattle
133 cattle
37004 m³ irr.
35850 m³ irr.
98679 m³ irr.
185022 m³ irr.
49339 m³ irr.
0300085
11 withdrawals
4350 m³/d dom(sw)
67842 m³ ind
62 643 m³ irr
PE 2096
PE 1858
0300306
5 withdrawals
6.14 m³/d dom(sw)
45.5 m³/d lim.
11 withdrawals
2.27 m³/d dom.(sw)
13.86 m³/d ind.
217210 m³ irr.
PE 331
3.80 m³/d dom.
PE 4258
PE 226
PE 236
SITE 5
PE 4643
6.82 m³/d lim.
9.09 m³/d dom.
12335 m³ irr.
2467 m³ irr.
13568 m³ irr.
0300086
17269 m³ irr.
CANADA
U.S.A.

Figure 3a: Locations of Waste Discharges, Water Quality Monitoring Sites, and Licenced Water Withdrawals of Little Campbell River Watershed.

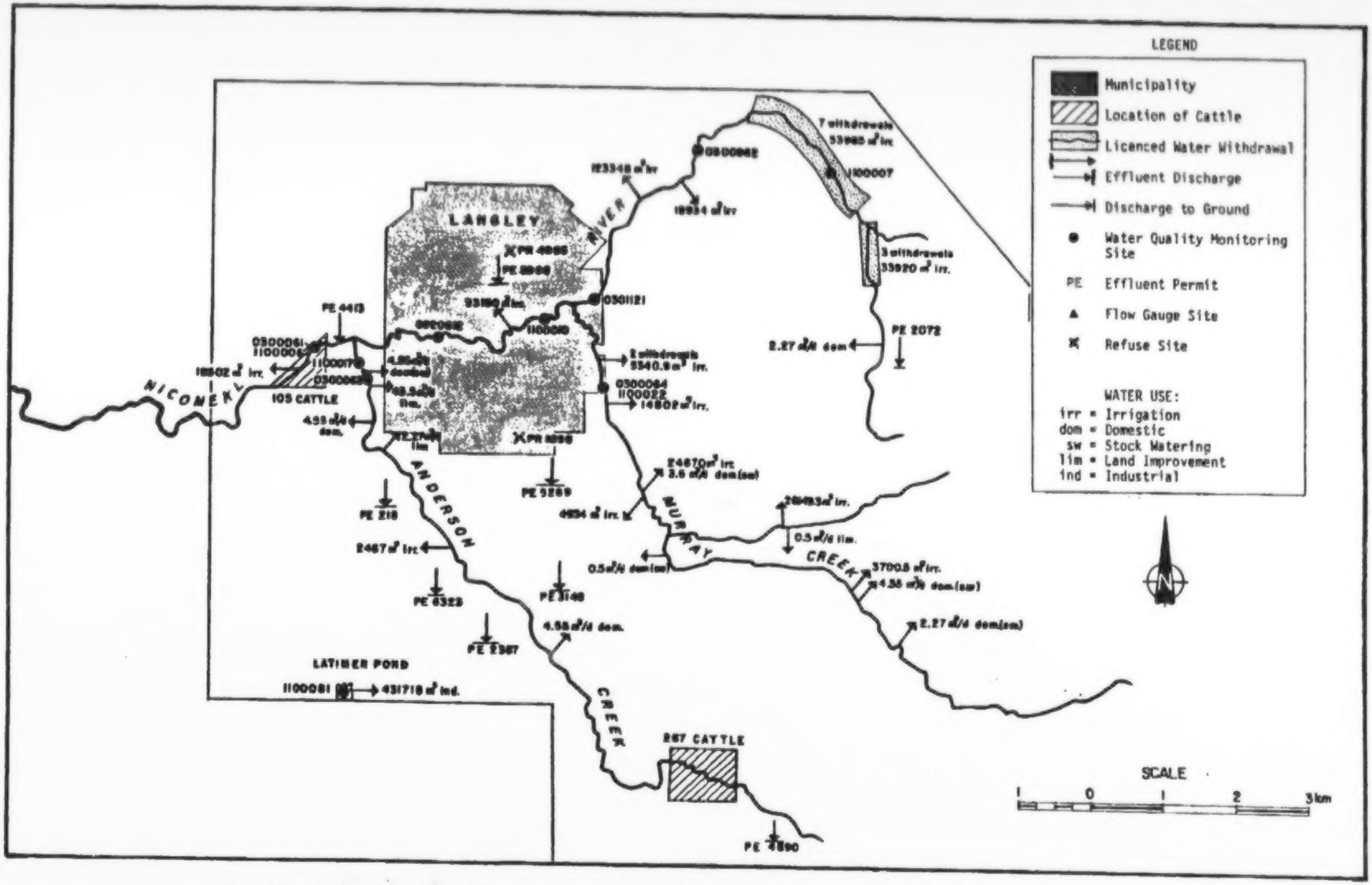
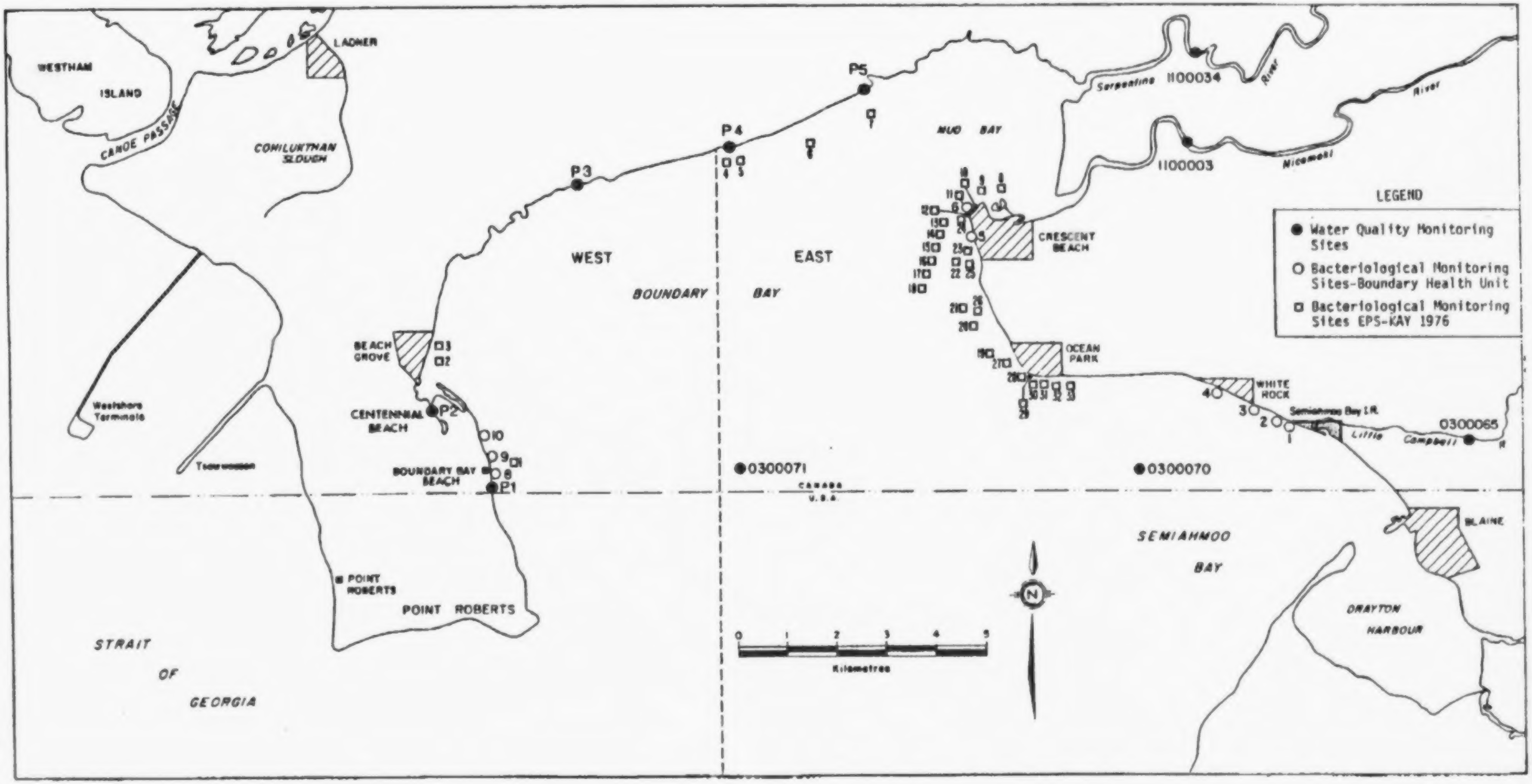

LEGEND
Municipality
Location of Cattle
Licenced Water Withdrawal
Effluent Discharge
Discharge to Ground
Water Quality Monitoring Site
PE Effluent Permit
Flow Gauge Site
Refuse Site
WATER USE:
irr = Irrigation
dom = Domestic
sw = Stock Watering
lim = Land Improvement
ind = Industrial
SCALE
1
0
1
2
3km
N
LANGLEY
NICOMEKL
RIVER
ANDERSON
CREEK
MURRAY
CREEK
LATIMER POND
105 CATTLE
267 CATTLE
PE 4413
PE 2072
PE 5269
PE 218
PE 6323
PE 3140
PE 2367
PE 4890
0300061
1100001
1100017
0300063
0300062
1100010
0301121
0300064
1100022
0300082
1100007
1100081
18502 m³ irr.
4.55 m³/d dom.
93180 m³ lim.
123348 m³ irr.
18934 m³ irr.
7 withdrawals
53985 m³ irr.
3 withdrawals
33920 m³ irr.
2.27 m³/d dom
2 withdrawals
5340.9 m³ irr.
14802 m³ irr.
24670 m³ irr.
3.6 m³/d dom(sw)
4934 m³ irr.
20493 m³ irr.
0.5 m³/d lim.
0.5 m³/d dom(sw)
3700.8 m³ irr.
4.35 m³/d dom(sw)
2.27 m³/d dom(sw)
2467 m³ irr.
4.55 m³/d dom.
431718 m³ ind.

Figure 3b: Location of Waste Discharges, Water Quality Sites, and Licenced Water Withdrawals of Upper Nicomekl Watershed.

FIGURE 4

LOCATION OF WATER QUALITY AND BACTERIOLOGICAL MONITORING SITES IN BOUNDARY BAY



WESTHAM
ISLAND
CANOE PASSAGE
LADNER
COHILUKTHAN SLOUGH
Westshore Terminals
Tsawwassen
STRAIT OF GEORGIA
POINT ROBERTS
POINT ROBERTS
BEACH GROVE
CENTENNIAL BEACH
BOUNDARY BAY BEACH
P1
P2
P3
P4
P5
WEST
BOUNDARY
EAST
BAY
MUD BAY
CRESCENT BEACH
OCEAN PARK
WHITE ROCK
Semiahmoo Bay I.R.
Little Campbell R
Serpentine 1100034 River
1100003 Nicomekl River
0300071
0300070
0300065
CANADA
U.S.A.
SEMIAHMOO BAY
BLAINE
DRAYTON HARBOUR
N
0 1 2 3 4 5
Kilometres
LEGEND
● Water Quality Monitoring Sites
○ Bacteriological Monitoring Sites-Boundary Health Unit
□ Bacteriological Monitoring Sites EPS-KAY 1976

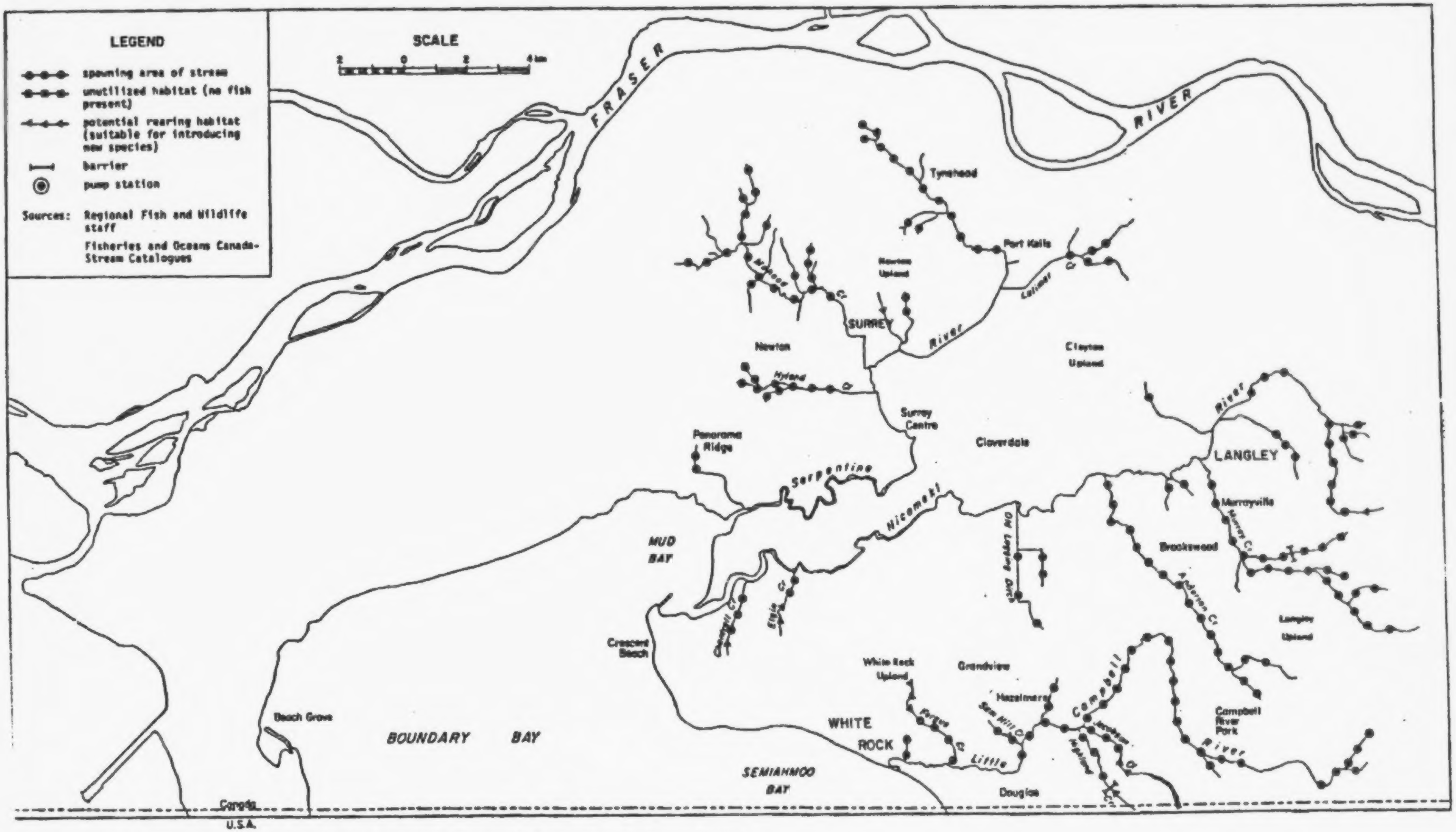

LEGEND
spawning area of stream
unutilized habitat (no fish present)
potential rearing habitat (suitable for introducing new species)
barrier
pump station
Sources: Regional Fish and Wildlife staff
Fisheries and Oceans Canada-Stream Catalogues
SCALE
2
0
2
4 km
FRASER
RIVER
Tynehead
Port Kells
Newton Upland
SURREY
River
Latimer Cr
Clayton Upland
Newton
Hyland Cr
Surrey Centre
Cloverdale
Panorama Ridge
Serpentine
Nicomekl
River
LANGLEY
Murrayville
Murray Cr
Brookswood
Anderson Cr
Langley Upland
Old Logging Ditch
MUD BAY
Crescent Beach
Chantrell Cr
Elgin Cr
White Rock Upland
Grandview
Hazelmere
Sam Hill Cr
Fergus Cr
Little
Campbell
Highland
Cr
Campbell River Park
River
WHITE ROCK
SEMIAHMOO BAY
Douglas
Beach Grove
BOUNDARY BAY
Canada
U.S.A.

Figure 5 Fish Spawning Areas in the Little Campbell, Nicomekl, Serpentine Drainage Basins.

TABLE 1
ESCAPEMENT RECORD FOR THE LITTLE CAMPBELL RIVER

YEAR	CHINOOK	COHO	CHUM	STEELHEAD
1947		1500	200	
1948		750	200	
1949		400	750	
1950		750	750	75
1951		3500	750	400
1952		1500	1500	400
1953		1500	1500	400
1954		750	0	
1955		400	200	75
1956		750	200	200
1957		400	75	
1958		400	75	
1959		750	25	
1960		400	75	
1961		400	75	
1962		200	25	
1963		400	25	
1964		750	75	
1965		200	25	
1966		400	75	
1967		200	0	
1968		200	0	
1969		200	25	
1970		750	200	
1971		750	200	
1972		7500	400	
1973		3500	200	
1974		3500	250	
1975		2200	400	
1976		3500	200	
1977		1500	100	
1978	50	2800	50	
1979	25	1500	75	
1980	30	2500	200	
1981	10	1900	149	
1982	75	3087	205	10
1983*	85	3000	700	

* Presence of one sockeye noted.

Timing of Spawning:		
Arrive	October	October
Start	Late October	Early November
Peak	Middle November	Middle November
End	Middle December	Late November

Mean salmon escapements to Little Campbell River, 1962 to 1978.

YEAR	COHO	CHUM
1962-1966	390	45
1967-1971	420	90
1972-1976	4 040	290
1977-1981	2 075	105

Data From: M.J. Hancock, Marshall, D.E. 1985. Catalogue of Salmon Streams and Spawning Escapements of Statistical Area 29. Canadian Data Report of Fisheries and Aquatic Science No. 495. Department of Fisheries and Oceans.

TABLE 2

EFFLUENT DATA SUMMARY
LAFARGE CONCRETE LTD. (PE 3331)

TRUCK WASHING OPERATION

Constituent	Period of Record	No. of Values	Values*		
			Maximum	Minimum	Mean
Coliform:fecal	1973	1	<2	-	-
Flow	1973-1978	4	243	1.2	68.5
Oxygen:BOD$_5$	1973	1	<5	-	-
pH	1973	1	6.35	-	-
Solids:					
Suspended	1973	1	27.2	-	-
Dissolved	1973	1	68	-	-
Total	1973	1	95	-	-

GRAVEL WASHING PLANT

Constituent	Period of Record	No. of Values	Values*		
			Maximum	Minimum	Mean
Coliform:fecal	1973	1	<2	-	-
Oxygen:BOD$_5$	1973	1	<5	-	-
Flow	1973-1977	241	3222.5	196.4	414.1
Solids:					
Suspended	1973	1	15.2	-	-
Dissolved	1973	1	399	-	-
Total	1973	1	414	-	-

*Values are as mg/L except:

1) Coliform-fecal as MPN/100 mL
2) Flow as m^3/d
3) pH

Data Source: Ministry of Environment and Parks

TABLE 3

EFFLUENT DATA SUMMARY
HAZELMERE RIVERSIDE CAMPGROUND, SURREY (PE 1558)

Constituent	Period of Record	No. of Values	Values*		
			Maximum	Minimum	Mean
Chloride	1975	1	166	-	-
Coliform:fecal	1975-1977	4	>240 000	>24 000	166 000+
Oxygen:BOD_5	1975-1978	10	462	32	225
pH	1975-1978	4	7.6	7.1	7.4+
Specific Conductivity	1975-1977	4	1 770	45	1 350
Solids: Total	1975-1978	11	446	5	106

*All values are as mg/L except:
- (1) Coliform as MPN/100 mL
- (2) pH
- (3) Specific Conductivity as µS/cm

+Median Value

Data Source: Ministry of Environment and Parks

TABLE 4

WATER QUALITY DATA SUMMARY

LITTLE CAMPBELL RIVER
SITE 0300066

Constituent	Period of Record	No. of Values	Maximum	Values* Minimum	Mean
Alkalinity:Total	1979-1983	10	71.6	14.7	37.6
Arsenic:Total	1982	2	<0.25	<0.25	<0.25
Chloride	1979-1982	8	9.3	4.3	6.3
Coliform:					
fecal	1979-1983	9	5400	8	90^{+}
Hardness:					
total	1979-1981	5	43.3	18.3	29.4
calcium	1979-1981	5	10.9	4.7	7.3
magnesium	1979-1981	5	3.9	1.6	2.8
Metals:Total					
Aluminum	1982	2	0.08	<0.02	-
Cadmium	1982	2	<0.01	<0.01	<0.01
Chromium	1982	2	<0.01	<0.01	<0.01
Copper	1982	2	<0.01	<0.01	<0.01
Iron	1979-1982	6	3.29	0.3	1.49
Lead	1981-1982	3	<0.1	<0.01	-
Manganese	1979-1982	7	1.29	<0.02	0.35
Molybdenum	1982	2	<0.01	<0.01	<0.01
Nickel	1982	2	<0.05	<0.05	<0.05
Vanadium	1982	2	<0.01	<0.01	<0.01
Zinc	1979-1982	7	0.007	<0.005	0.007
Nitrogen:					
Ammonia	1979-1983	9	0.389	0.009	0.111
Nitrate	1979-1983	10	2.14	<0.02	0.98
Nitrite	1979-1983	10	0.024	<0.005	0.01
Organic	1979-1983	10	1.64	0.39	0.84
Nitrate/Nitrite	1979-1983	10	2.16	<0.02	0.99
Kjeldahl	1979-1983	10	1.91	0.44	0.91
Oxygen:					
dissolved	1979-1983	9	10.2	2.7	6.5
%saturation	1979-1982	9	76.1	30.1	56.7
pH	1979-1983	10	7.0	6.5	6.8^{+}
Phosphorus					
ortho diss.	1979-1982	8	0.101	0.013	0.037
total diss.	1979-1982	8	0.141	0.026	0.062
Potassium:Dissolved	1979-1982	8	3.8	1.4	2.4
Sodium:Dissolved	1979-1982	8	9.6	4.0	5.6
Solids:					
Dissolved	1979-1983	10	108	66	83.5
Suspended	1979-1983	10	22	2	7
Total	1979-1983	10	130	70	90

TABLE 4 (Continued)

Constituent	Period of Record	No. of Values	Maximum	Values* Minimum	Mean
Specific Conductivity	1979-1983	10	174	74	111
Sulphate	1979-1982	8	12.8	2.7	5.7
Temperature	1979-1983	9	17.5	0.3	10.3

*All values are as mg/L except:
(1) Coliform as MPN/100 mL
(2) pH
(3) Temperature as °C
(4) Specific conductivity as µS/cm
(5) % saturation as %

+Median value

Data Source: Ministry of Environment and Parks

TABLE 5
WATER QUALITY DATA SUMMARY
LITTLE CAMPBELL RIVER
SITE 0300065

Constituent	Period of Record	No. of Values	Maximum	Values* Minimum	Mean
Alkalinity:Total	1979-1983	10	66.1	18.2	44.4
Arsenic:Total	1982	2	<0.25	<0.25	<0.25
Chloride	1979-1982	8	13.4	6.0	9.3
Coliform: fecal	1979-1983	9	9200	130	625 +
Hardness:					
total	1979-1981	5	57.8	23.6	37.8
calcium	1979-1981	5	14.4	6.0	9.3
magnesium	1979-1981	5	5.3	2.1	3.5
Metals:Total					
Aluminum	1982	2	0.34	0.11	0.22
Cadmium	1982	2	<0.01	<0.01	<0.01
Chromium	1982	2	<0.01	<0.01	<0.01
Copper	1979-1982	7	0.002	<0.001	0.001
Iron	1979-1982	7	2.2	0.20	1.05
Lead	1979-1982	7	0.011	<0.001	0.007
Manganese	1979-1982	7	0.08	0.05	0.06
Molybdenum	1982	2	0.01	<0.01	-
Nickel	1982	2	<0.05	<0.05	<0.05
Vanadium	1982	2	<0.01	<0.01	<0.01
Zinc	1982	2	0.02	<0.01	-
Nitrogen:					
Ammonia	1979-1983	9	0.320	0.016	0.107
Nitrate	1979-1983	10	2.39	0.93	1.43
Nitrite	1979-1983	10	0.024	0.007	0.014
Organic	1979-1983	10	2.10	0.27	0.66
nitrate/nitrite	1979-1983	10	2.40	0.75	1.45
Kjeldahl	1979-1982	8	2.34	0.29	0.73
Oxygen:					
dissolved	1979-1983	9	14.2	8.4	8.8
% saturation	1979-1983	9	139.2	79.5	100.0
pH	1979-1983	10	8.6	6.9	7.6+
Phosphorus:					
ortho - dissolved	1979-1983	10	0.090	0.015	0.048
total - dissolved	1979-1983	10	0.122	0.021	0.064
Potassium:Dissolved	1979-1982	8	3.3	1.4	2.2
Sodium:Dissolved	1979-1982	8	13.3	5.9	9.7
Solids:					
Dissolved	1979-1983	10	142	76	105.3
Suspended	1979-1983	10	63	4	16.7
Total	1979-1983	10	186	98	122.0
Specific Conductivity	1979-1983	10	218	92	149.2
Sulphate	1979-1982	8	14.6	5.1	8.0
Temperature	1979-1983	9	16.8	0.5	9.1

*All values are as mg/L except:
(1) pH
(2) Temperature as °C
(3) % saturation as %
(4) Specific conductivity as µS/cm
+Median value
Data Source: Ministry of Environment and Parks

TABLE 6

TOTAL AMMONIA VALUES: LITTLE CAMPBELL RIVER

	Temperature °C	pH	Total Ammonia-N mg/L	Maximum Concentration of Total Ammonia-N for Protection of Aquatic Life[8] mg/L	Average 30-day Concentration of Total Ammonia-N for Protection of Aquatic Life[8] mg/L
Site 0300065					
February, 1979	3	6.9	0.320	23.5	1.99
August, 1980	-	7.9	0.045	-	-
February, 1981	7.6	7.4	0.241	14.7	1.89
May, 1981	16.8	7.7	0.065	9.2	1.56
November, 1981	3.2	7.2	0.097	19.0	1.98
May, 1982	11	8.3	0.023	3.0	0.57
September, 1982	13	8.6	0.016	1.5	0.30
November, 1982	0.5	7.4	0.118	16.1	2.06
July, 1983	16.4	7.6	0.041	10.7	1.62
August, 1983	14.8	7.7	0.036	9.3	1.79
Site 0300066					
February, 1979	2	6.5	0.386	27.9	2.02
August, 1980	-	6.8	0.048	-	-
February, 1981	7.5	6.9	0.275	22.3	1.89
May, 1981	17.5	6.9	0.114	20.7	1.48
November, 1981	2.9	6.8	0.049	24.8	1.99
September, 1982	11	7.0	0.038	18.5	1.83
November, 1982	0.3	6.5	0.057	27.9	2.07
July, 1983	19.2	6.9	0.061	20.5	1.30
August, 1983	18.8	7.0	0.009	19.3	1.34

Data Source: Ministry of Environment and Parks

TABLE 7

BIOLOGICALLY AVAILABLE NITROGEN - TOTAL DISSOLVED PHOSPHORUS RATIOS: LITTLE CAMPBELL RIVER

Date	Site 0300066			Site 0300065		
	Nitrate + Ammonia (mg/L)	Total Dissolved Phosphorus (mg/L)	N:P Ratio	Biologically Available Nitrogen* (mg/L)	Total Dissolved Phosphorus (mg/L)	N:P Ratio
Feb. 1979	2.529	0.082	30.8	2.71	0.088	30.8
Sept. 1980	0.058	0.031	1.9	1.71	0.036	47.5
Feb. 1981	2.155	0.054	39.9	1.88	0.122	15.4
May 1981	0.975	0.080	12.2	1.03	0.059	17.5
Nov. 1981	1.919	0.067	28.6	2.11	0.066	32.0
May 1982	1.018	0.038	16.8	1.01	0.021	48.1
Sept. 1982	0.075	0.056	1.3	0.95	0.050	19.0
Nov. 1982	1.917	0.043	44.6	1.87	0.067	21.9
July 1983	-	0.141	-	-	0.077	-
Aug. 1983	-	0.026	-	1.31	0.058	22.5

Data Source: Ministry of Environment and Parks

TABLE 8

SEDIMENT CHEMISTRY ANALYSES
LITTLE CAMPBELL RIVER AND OTHER B.C. SITES

CONSTITUENT	LITTLE CAMPBELL RIVER				FRASER RIVER SEDIMENTS						
	SITE 1 NEAR HWY. 99	0300065	SITE 5 NEAR 200 STREET	0300066	N. WESTMINSTER[1] SOUTH OF MIDSTREAM	OAK ST. BRIDGE[1] SOUTH OF MIDSTREAM	N. WESTMINSTER[2] SOUTH OF MIDSTREAM	OAK ST. BRIDGE[2] SOUTH OF MIDSTREAM	SEDIMENTS FROM B.C. LAKES[23]	RESIDENTIAL STORMWATER SEDIMENTS[24]	SQUAMISH ESTUARY[3]
METALS											
Aluminum+	8.23	7.65	9.09	10.4					0.94-60.40	4.60-8.02	
Barium#	39	47	53	51					15 -1860		
Boron#	3	<1.0	5	6					1 - 441		
Cadmium#	<1.0	<1.0	<1.0	3	0.1-0.2	0.1	0.1-0.2	0.1-0.3	1 - 11	<1.0-19	
Calcium+	2.87	2.27	2.96	2.87					0.3 - 361		
Chromium#	30	28	37	34					1 - 120		
Copper#	10	9	9	250	9.6-14	6.0-6.9	19.0-23.0		4 - 205	22-29	80
Iron+	15	11.7	19.8	17	3.1-3.3	4.0-4.3	5.3-6.1	5.0-7.8	0.3 - 128	11-13.4	
Lead#	80	100	24	30	2.1-2.4	3.5-3.7	2.5-3.0	5.3-7.6	10 - 560	160-209	
Magnesium+	5.08	4.2	5.16	5.06					0.57- 273		
Manganese#	268	297	843	366	150	120-130	170-190	150-190	11 -9660		
Molybdenum#	8	7	11	13					1 - 183		
Nickel#	18	19	23	27	12-13	13.0-14.0	17.0-20.0	17.0-26.0	5 - 471		
Selenium#	<10.0	<10.0	13	<10.0					10 - 85		
Strontium#	14	13	14	15					2 -1790		
Tellurium#	30	38	56	70					20 - 604		
Thallium#	<20.0	<20.0	31	30					20 - 122		
Tin#	<5.0	<5.0	<5.0	<5.0					5 - 42		
Titanium#	496	387	619	469					1 -3610		
Vanadium#	30	22	40	31					1 - 203		
Zinc#	48	270	49	94	9-10	17.0-19.0	13.0-15.0	31.0-42.0	8 - 402	101-183	

+Unit - mg/g dry weight

#Unit - µg/g dry weight

[1] Analyses on sediments with particle size >180 µm, <850 µm; by Stancil; Ministry of Environment (1980)

[2] Analyses on sediments with particle size <180 µm; by Stancil; Ministry of Environment (1980)

[3] Squamish Estuary, Air and Water Quality Work Group. 1981.

[23] C. McKean; Ministry of Environment and Parks (unpublished)

[24] L. Swain; Ministry of Environment (1983)

TABLE 8 (Continued)

Constituent[+]	LITTLE CAMPBELL RIVER				ADJACENT TO IONA STP[21]	FROM B.C. LAKES[22]	SQUAMISH ESTUARY[5]
	SITE 1 NEAR HWY. 99	0300065	SITE 5 NEAR 200 STREET	0300066			
Carbon							
Organic	2.0	5.8	<0.3	23.0		1.0-382.0	0.5-67.0
Nitrogen							
Kjeldahl	0.2	0.6	0.4	2.8	0.221-0.728	0.30-41.50	
Residue							
% Total Vol.	1.5	2.4	1.9	11.1		2.70-84.8	
Oxygen							
B.O.D.$_5$	0.36	0.76	0.67	1.97			
Phosphorus							
Total	0.468	0.424	0.515	0.699	0.588-0.910	0.245-4.44	

[+] Unit: mg/g dry weight

[5] Squamish Estuary, Air and Water Quality Work Group. 1981.

[22] C. McKean; Ministry of Environment (Unpublished)

[21] D. Stancil; Fraser River Estuary Study. Aquatic Biota and Sediments 1980.

TABLE 9
ESCAPEMENT VALUES FOR THE SERPENTINE RIVER

YEAR	COHO	STEELHEAD
1947	750	0
1948	1500	
1949	400	
1950	1500	
1951	1500	75
1952	1500	
1953	1500	
1954	750	
1955	750	
1956	1500	
1957	400	
1958	750	
1959	1500	
1960	400	
1961	400	
1962	400	
1963	400	
1964	750	
1965	400	
1966	400	
1967	200	
1968	200	
1969	75	
1970	750	
1971	3500	
1972	1500	
1973	1500	
1974	2000	
1975	2800	
1976	3500	
1977	2400	
1978	1800	
199	1500	
1980	500	
1981*	1100	
1982**	600	
1983	350	

* 2 chinook ** 4 chinook

Timing of Spawning:

Arrive	October
Start	Late October
Peak	Middle November
End	Late December

Data From: M.J. Hancock, Marshall, D.E. 1985. Catalogue of Salmon Streams and Spawning Escapements of Statistical Area 29. Canadian Data Report of Fisheries and Aquatic Science No. 495. Department of Fisheries and Oceans.

TABLE 10
EFFLUENT DATA SUMMARY
ASSOCIATED FOUNDRY LTD. SURREY (PE 1529)

CONSTITUENT	PERIOD OF RECORD	NO. OF VALUES	VALUES*			LEVEL "C" OBJECTIVES
			MAXIMUM	MINIMUM	MEAN	
pH	1978-1982	36	11.2	5.4	7.03^+	6.5-8.5
Oil/grease	1978-1982	37	60	2	19.9	15
Solids						
Suspended	1978-1982	36	246	4	77.2	100
Flow	1978-1982	12	63	46	53.4	
Arsenic:Total	1980	1	<0.05	-	-	1
Hardness:calcium	1980	1	2.61	-	-	-
magnesium	1980	1	0.34	-	-	-
METALS:Total						
Cadmium	1980	1	<0.01	-	-	0.10
Chromium	1980	1	<0.01	-	-	0.60
Copper	1980	1	<0.01	-	-	1
Iron - dissolved	1980	1	1.9	-	-	1
- total	1980	1	2.43	-	-	-
Manganese	1980	1	0.05	-	-	1
Molybdenum	1980	1	<0.01	-	-	10
Nickel	1980	1	<0.05	-	-	2
Zinc	1980	1	0.06	-	-	1
Oxygen:BOD_5	1980	1	<10	-	-	-
Oil & Grease	1980	18	60	3	19.7	15
pH	1979-1980	17	7	6	6.69+	6.5-8.5
Phosphorus: total	1980	1	<0.5	-	-	5
Solids: suspended	1979-1980	17	246	4	90	100
Specific Conductivity	1979-1980	5	27	21	23	-
Temperature	1979-1980	3	34	28	31.3	-

* All values are mg/L except:
1) pH
2) Specific Conductivity as uS/cm
3) Temperature as °C
4) Flow as m^3/d

+ Median Value
Data Source: Ministry of Environment and Parks

NOTE: Level "C" objectives are for industries which discharge metals.

TABLE 11(a)
WATER QUALITY DATA SUMMARY
SERPENTINE RIVER

Constituent	Site 1100032 Serpentine River at Freeway				
	Period of Record	No. of Values	Values*		
			Maximum	Minimum	Mean
Colour: True	1981	2	15	15	15
Carbon: Organic	1981	2	3	2	2.5
Inorganic	1981	2	13	13	13
Coliform: fecal	1981	5	2200	230	790$^+$
Chloride: dissolved	1981	2	6.4	5.8	6.1
Nitrogen:					
Ammonia	1981	2	0.007	0.005	0.006
Nitrate	1981	2	0.44	0.44	0.44
Nitrite	1981	2	0.006	0.006	0.006
Nitrate/Nitrite	1981	2	0.45	0.45	0.45
Oxygen: BOD_5	1981	2	< 10	< 10	<10
COD	1981	2	13	< 10	<10
Oil/Grease	1981	2	2	1.2	1.6
pH	1981	2	7.8	7.8	7.8
Phosphorus:ortho-diss.	1981	2	0.020	0.016	0.018
total dissolved	1981	2	0.028	0.021	0.024
total	1981	2	0.03	0.03	0.03
Potassium dissolved	1981	2	1.6	1.4	1.5
Sodium dissolved	1981	2	6.9	6.4	6.65
Solids: total	1981	2	100	98	99
Suspended	1981	2	2	1	1.5
Dissolved	1981	2	99	97	98
Suspended Inorganic	1981	2	1	< 1	-
Specific Conductivity	1981	2	139	127	133
Silica: Reactive	1981	2	18.6	17	17.8
Sulphate	1981	2	6.3	5.4	5.85
Tannin & Lignin	1981	2	0.4	0.4	0.4

* All values are as mg/L except:
(1) pH
(2) Specific conductivity as μS/cm
(3) Colour as true colour units

$^+$ Median value

Data Source: Ministry of Environment and Parks

TABLE 11(a) Continued

Constituent	Site 0300057 Serpentine R. King George Hwy				
	Period of Record	No. of Values	Values*		
			Maximum	Minimum	Mean
Alkalinity: total	1972,1983	43	102.	8.5	46.7
Boron: dissolved	1972	3	0.7	< 0.1	0.2+
Carbon: Organic	1981-1983	27	18	6	11.7
Inorganic	1981-1983	20	21	9	15.1
Chloride	1972-1983	44	13 800	10.8	1229
Coliforms: fecal	1973-1983	51	>24 000	< 20	110 +
total	1972-1977	19	>24 000	140	>1609^{+}
Colour:True	1972-1982	20	160	30	79.5
Hardness:total	1972-1982	30	4580	40.5	588.
calcium	1972-1982	30	292	9.8	47.4
magnesium	1972-1982	30	935	3.9	115
Metals: (Total)					
Aluminum	1982-1983	6	1.32	0.51	0.83
Cadmium	1974-1982	8	< 0.01	< 0.0005	-
Chromium	1972-1983	23	0.016	< 0.005	0.006^{+}
Copper	1972-1983	36	0.03	0.001	0.006
Iron	1973-1983	36	3.6	0.7	1.61
Lead	1972-1982	39	< 0.1	< 0.001	0.005^{+}
Manganese	1972-1983	36	0.46	0.06	0.19
Molybdenum	1975-1983	7	0.05	0.002	< 0.01^{+}
Zinc	1972-1983	39	0.08	< 0.005	0.019
Nitrogen:					
Ammonia	1974-1983	52	0.532	< 0.005	0.142
Nitrate	1972-1983	46	2.83	< 0.02	0.63
Nitrite	1972-1983	61	0.246	< 0.005	0.022
nitrate/nitrite	1975-1983	47	2.86	< 0.02	0.66
Kjeldahl	1972-1983	51	3.62	0.43	1.17
Organic	1973-1983	46	3.16	0.39	1.05
Oxygen: BOD_5	1981-1982	8	< 10.	< 10	< 10
dissolved	1972-1983	44	15.6	2.7	9.4
COD	1981-1982	31	65.	13	40.9
% Saturation	1972-1983	44	176.5	24.7	90.5
Oil and Grease	1981	5	4.	1.2	2.2
pH	1972-1983	61	8.9	6.2	7.2 +
Phenol	1982	3	0.006	< 0.002	0.003
Phosphorus:ortho-diss.	1973-1983	57	0.122	< 0.003	0.032
total	1972-1983	37	0.262	0.07	0.139
total dissolved	1976-1983	43	0.153	0.016	0.050
Potassium: diss.	1972-1983	41	28.6	2.2	24.9
Silica	1972-1982	11	19.1	11.7	15.0
Sodium:dissolved	1972-1982	40	7680	9.5	610
Solids:Suspended	1974-1983	49	57	9	24
Dissolved	1972-1983	22	26 500	118	4297
total	1972-1983	40	9790	142	1388
Specific Conductivity	1972-1982	62	36 000	156	3168
Sulphate	1972-1981	42	1804	19.6	182
Tannin/Lignin	1981	14	2.8	1.4	2.1
Temperature	1972-1983	44	27.5	1.8	12.3
Turbidity	1972-1983	8	36	7.2	15.9

* All values are as mg/L except
(1) Coliforms as MPN/100 mL (2) Colour as colour units (3) pH
(4) Temperature as °C (5) Turbidity as N.T.U. (6) Specific Conductivity as µS/cm
(7) % Saturation or %

+ Median Value
Data Source: Ministry of Environment and Parks

TABLE 11(a) Continued

Constituent	Site 1100034 Serpentine River at Hwy 99				
	Period of Record	No. of Values	Values*		
			Maximum	Minimum	Mean
Alkalinity: total	1979-1982	6	98.6	27.7	65.8
Arsenic:Total	1981	1	< 0.05	-	-
Boron dissolved	1979	1	0.1	-	
Chloride	1979-1982	4	13900	123	6432
Coliforms: fecal	1979-1981	2	1100	43	-
total	1979	1	>2400	-	-
Colour:True	1979-1982	7	150	15	60
Hardness:total	1979-1982	6	4380	78.9	1423
Calcium	1979-1981	6	350	15.6	104
Magnesium	1979-1982	6	880	9.7	283
Metals:(total)					
Cadmium	1981	1	< 0.01	-	
Copper	1979-1982	5	0.05	0.002	0.015
Iron	1979-1982	5	3.4	0.4	1.66
Lead	1979-1982	6	0.009	0.002	0.005
Zinc	1979-1982	6	0.11	0.005	0.032
Nitrogen:					
Ammonia	1979-1982	3	0.25	< 0.01	0.097
Nitrate	1981	1	0.40	-	-
Nitrite	1981	1	0.01	-	-
Nitrate/Nitrite	1979-1981	7	1.82	< 0.02	0.544
Kjeldahl	1979-1982	6	2	0.44	1.12
Organic	1979-1982	4	2	0.44	1.17
Total	1979-1982	6	3	0.49	1.65
Oxygen: COD	1981	1	16.5	-	-
Dissolved	1979	3	8.5	2.5	5.1
pH	1979-1981	8	8.5	6.7	7.8+
Phenol	1981	1	0.006	-	-
Phosphorus:ortho-diss.	1979-1982	5	0.101	0.011	0.074
total	1979-1982	7	0.202	0.127	0.173
Potassium dissolved	1979-1982	4	280	5	130
Sodium dissolved	1979-1982	4	7750	83.5	3603
Solids:Suspended	1979-1981	7	44	5	30
dissolved	1979-1981	7	27399	121	7420
total	1979-1982	7	27700	126	7488
Specific Conductivity	1979-1982	7	38700	163	106
Sulphate Dissolved	1979-1982	4	1811	27	839
Tannin/Lignin	1981	1	1.4	-	-
Temperature	1979-1982	5	21	7	16.7
Turbidity	1979-1981	6	25	11	16.5

* All values are as mg/L except:
(1) Coliform as MPN/100 mL (2) Colour as colour units (3) pH
(4) Temperature as °C (5) Turbidity as N.T.U., (6) Specific Conductivity μS/cm
+ Median value
Data Source: Ministry of Environment and Parks

TABLE 11(a)-Continued

Constituent	Site 1100033 Serpentine River at Flood Gate				
	Period of Record	No. of Values	Values*		
			Maximum	Minimum	Mean
Alkalinity	1974-1979	26	98.5	13	58.
Arsenic:Total	1974	2	< 0.005	< 0.005	<0.005
Boron:Total	1974-1979	23	3.2	< 0.1	1.64
Carbon: Organic	1974-1981	24	31	< 1	10.3
Inorganic	1981	2	14	13	13.5
Chloride: dissolved	1974-1981	32	14500	5.8	6268
Coliforms: fecal	1976-1981	10	2400	170	490 +
Colour: True	1976-1981	18	100	20	51.9
Fluoride	1976	1	< 0.1	-	-
Hardness:total	1976-1979	20	4050	25	865
calcium	1974-1979	41	306	6.4	124
magnesium	1974-1979	41	939	2.2	377
Metals: (Total)					
Cadmium	1974	1	< 0.0005	-	-
Iron	1976-1977	11	3.7	0.2	1.89
Lead	1974	1	0.002	-	-
Mercury	1974	1	< 0.0005	-	-
Zinc	1974	1	0.014	-	-
Nitrogen:Ammonia	1976-1981	13	0.175	0.018	0.062
Nitrate/Nitrite	1974-1981	44	2.65	< 0.002	0.54
Nitrate	1981	2	0.68	0.46	0.57
Nitrite	1981	2	0.008	0.007	0.008
Organic	1978-1979	6	2	0.03	0.99
Kjeldahl	1974-1981	42	10	0.05	1.1
Total	1974-1979	12	4	0.05	1.57
Oxygen: BOD_5	1981	2	< 10	< 10.	<10
COD	1981	2	22	13.	17.5
Dissolved	1974-1981	32	24	3.8	9.68
% saturation	1974-1981	31	278.7	43.7	101.1
Phosphorus:ortho	1974-1981	35	0.728	< 0.003	0.062
total dissolved	1974-1981	37	0.773	0.014	0.081
total	1974-1981	44	1.29	0.052	0.164
pH	1974-1981	44	8.5	6.2	7.35+
Potassium:dissolved	1974-1981	34	299	1.8	127
Sodium:dissolved	1974-1981	30	7950	7.1	3534
Solids:Total	1979-1981	4	1922	94	635
Suspended	1976-1981	5	46	5	22
dissolved	1976-1981		41876	87	615
Silica: Reactive	1981	2	17	14.8	15.9
Sulphate	1974-1981	29	1928	5.3	887
Tannin/Lignin	1981	2	0.8	0.7	0.75
Salinity	1974-1981	30	22800	0.	8380.
Turbidity	1974-1981	41	74	4.8	14.6
Specific Conductivity	1974-1981	46	39800	91.	15116
Temperature	1974-1981	41	25.5	3.1	14.5
Turbidity	1974-1979	41	74	4.8	14.6

* All values are as mg/L except:
(1) pH (2) Temperature as °C (3) Specific conductivity as µS/cm
(4) Colour as colour units (5) Turbidity as NTU (6) % Saturation as %

+ Median value

Data Source: Ministry of Environment and Parks

TABLE 11(a) (Continued)

Constituent	Site 1100035 Serpentine River at Hwy 10				
	Period of Record	No. of Values	Values*		
			Maximum	Minimum	Mean
Alkalinity: total	1974-1979	18	69	14	44.4
Arsenic: diss.	1974	1	< 0.005	-	-
Boron: dissolved	1974-1979	22	1.8	< 0.1	0.24
Carbon: organic	1974-1981	25	42	5	13.8
inorganic	1981	3	26	19	21.7
Chloride	1974-1981	31	9200	6.1	580
Coliforms: fecal	1981	8	>24000	330	490 +
Colour: True	1976-1981	17	150	30	65.3
Hardness: total	1976-1979	14	111	26.8	62
calcium	1974-1979	35	200	6.6	23.3
magnesium	1974-1979	35	608	2.1	38.6
Metals: (total)					
Cadmium	1974-1981	15	< 0.01	< 0.0005	-
Chromium	1974	2	< 0.005	< 0.005	< 0.005
Copper	1974-1981	8	0.014	0.001	0.006
Iron	1974-1979	25	6.5	0.8	1.96
Lead	1974-1981	32	< 0.1	< 0.001	0.009
Mercury	1974-1975	16	0.00006	< 0.00005	<0.00005
Zinc	1974-1981	21	0.13	< 0.005	0.02
Nitrogen:					
Ammonia	1976-1981	16	0.735	0.014	0.245
Nitrate	1981	4	0.79	0.02	0.53
Nitrite	1981	4	0.044	< 0.005	0.021
Nitrate/Nitrite	1974-1981	40	3.3	< 0.02	0.68
Kjeldahl	1974-1981	38	3	0.59	1.40
Organic	1978-1981	8	3	0.43	1.33
Total	1974-1979	12	4	1.02	2.37
Oil & Grease	1981	1	1.5	-	-
Oxygen: BOD_5	1981	3	55	< 10	25.
Dissolved	1974-1979	27	15.8	4.1	9.9
COD	1981	5	133	20.2	61.1
% saturation	1974-1979	27	180.5	43	102.2
pH	1974-1981	41	8.3	6	7.0 +
Phenol	1981	1	0.007	-	-
Phosphorus: ortho diss.	1974-1981	33	1.01	0.01	0.099
total diss.	1974-1981	36	0.68	0.026	0.095
total	1974-1981	40	1.56	0.075	0.221
Potassium: dissolved	1974-1981	33	191	1.4	14
Silica	1981	3	19.2	14.5	17.2
Sodium: dissolved	1974-1981	30	5100	6	336
Solids: Suspended	1974-1981	8	82	17	43
dissolved	1979-1982	5	282	123	231
total	1974-1981	6	396	160	295
Specific Conductivity	1974-1981	43	36300	99	1648
Sulphate	1974-1981	28	1180	9.7	110
Tannin/Lignin	1981	5	4.4	1.9	2.8
Temperature	1974-1979	31	22	2.7	14.6
Turbidity	1974-1979	36	76	4.7	17.4

* All values are as mg/L except:
(1) Coliform as MPN/100 mL (2) Colour as true colour units (3) pH
(4) Temperature as °C (5) Turbidity as NTU, (6) Specific Conductivity as µS/cm
(7) % saturation as %

+ Median value

Data Source: Ministry of Environment and Parks

TABLE 11(a) Continued

Constituent	Site 1100049 Serpentine River at 64 Ave				
	Period of Record	No. of Values	Values*		
			Maximum	Minimum	Mean
Alkalinity: total	1974-1979	22	113	< 0.5	25.7
Boron:dissolved	1974-1979	18	0.3	< 0.1	0.17
Chloride	1974-1979	24	556	9.5	98.9
Colour: true	1976-1979	14	400	5	86
Hardness:total	1976-1979	18	568	60.4	268
calcium	1974-1979	32	85.5	7.5	40.5
magnesium	1974-1979	32	86.5	3.8	38.6
Metals: (total)					
Cadmium	1974-1975	13	0.007	< 0.0005	0.0008+
Chromium	1974	2	< 0.005	< 0.005	< 0.005
Copper	1974	3	0.03	0.003	0.004+
Iron	1974-1977	21	33.4	0.6	5.3
Lead	1974-1975	13	0.006	< 0.001	0.002
Mercury	1974-1975	13	< 0.00005	< 0.00005	< 0.00005
Zinc	1974-1975	13	0.24	< 0.005	0.09+
Nitrogen:					
Ammonia	1976-1979	14	0.572	0.023	0.219
Nitrate/nitrite	1974-1979	32	10.1	< 0.02	1.29
Kjeldahl	1974-1979	32	3	0.37	1.33
Organic	1978-1979	6	2	0.49	1.17
Total	1976-1979	11	11	0.84	3.22
Oxygen: dissolved	1974-1979	28	17.6	2.4	8.6
% saturation	1974-1979	27	180.4	26.6	84.8
pH	1974-1979	32	7.7	3.8	5.1 +
Phosphorus:ortho diss.	1974-1979	28	0.123	< 0.003	0.019
total diss.	1974-1979	27	0.153	0.003	0.033
total	1974-1979	32	0.22	0.011	0.073
Potassium:Dissolved	1974-1979	23	14.8	2.3	5.8
Sodium:Dissolved	1974-1979	23	314	7.4	83
Solids:Suspended	1976-1979	3	63	4	29
Dissolved	1979	1	210	-	-
total	1979	1	214	-	-
Specific Conductivity	1974-1979	34	2060	127	910
Sulphate	1974-1979	22	664	13.7	280
Temperature	1974-1979	31	26	2.6	15.1
Turbidity	1974-1979	30	192	3.4	26

* All values are as mg/L except:
(1) pH (2) Temperature as °C (3) Turbidity as NTU
(4) Specific Conductivity as µS/cm (5) % saturation as %

+ Median value
Data Source: Ministry of Environment and Parks

TABLE 11(a) Continued

Constituent	Site 1100036 Serpentine River at 80 Ave				
	Period of Record	No. of Values	Values*		
			Maximum	Minimum	Mean
Alkalinity: total	1974-1979	22	81.8	12.5	46.6
Boron:Dissolved	1974-1979	21	0.1	< 0.1	< 0.1+
Carbon: organic	1974-1981	23	20	3	10.7
inorganic	1981	2	15	15	15
Chloride	1974-1981	30	196	4.2	29
Coliforms: fecal	1981	1	790	-	-
Colour:True	1976-1982	15	150	10	57.7
Hardness:total	1976-1979	17	62.1	15.1	45.4
calcium	1974-1979	38	15.8	8.9	10.2
magnesium	1974-1979	38	15.9	1.3	4.6
Metals: (total)					
Iron	1976-1977	9	4.6	1.0	2.0
Nitrogen:					
Ammonia	1976-1981	14	0.277	0.017	0.168
Nitrate	1981	2	1.01	1.01	1.01
Nitrite	1981	2	0.019	0.019	0.019
Nitrate/nitrite	1974-1981	40	3.32	0.11	0.744
Kjeldahl	1974-1979	39	3	0.13	0.93
Organic	1978-1979	4	1	0.72	0.89
Total	1974-1979	11	3	0.31	1.60
Oxygen: BOD_5	1981	2	< 10	< 10	<10
Dissolved	1974-1979	29	14.2	5.0	8.9
COD	1981	2	17	17	17
% saturation	1974-1979	29	164.9	55.5	87.9
Oil & Grease	1981	1	1.5	-	-
pH	1974-1981	40	8.4	6.0	7.2+
Phosphorus:ortho-diss.	1974-1981	32	0.132	0.022	0.074
total diss.	1979-1981	35	0.159	0.041	0.091
total	1974-1981	41	0.432	0.033	0.168
Potassium:dissolved	1974-1981	31	6.1	0.8	2.4
Silica	1981	2	16	16	16
Sodium:dissolved	1974-1981	31	122	4.3	22.4
Solids:Suspended	1974-1981	8	38	4	21
Dissolved	1979-1982	2	145	100	122
total	1974-1981	5	194	104	140
Specific Conductivity	1974-1981	42	860	58	205
Sulphate	1974-1981	26	34.2	<5	11.9
Tannin/Lignin	1981	2	0.4	0.4	0.4
Temperature	1974-1979	34	21.5	2.9	13.3
Turbidity	1974-1979	39	54	1.7	15.5

* All values are as mg/L except:
(1) Coliform as MPN/100 mL (2) Colour as colour units (3) pH
(4) Temperature as °C (5) Turbidity as N.T.U. (6) Specific Conductivity µS/cm
(7) % saturation as %

+ Median value

Data Source: Ministry of Environment and Parks

TABLE 11(a) Continued

Constituent	Site 0300059 Serpentine River 80 Ave				
	Period of Record	No. of Values	Values*		
			Maximum	Minimum	Mean
Alkalinity: total	1972-1983	48	76.6	13	44
Boron: diss.	1972	3	< 0.2	< 0.1	< 0.1+
Carbon: Organic	1981-1983	21	23	4	10.1
Inorganic	1981-1983	14	22	17	19.5
Chloride	1972-1983	42	235	5.2	34.2
Coliforms: fecal	1973-1983	55	9200	40	1300 +
Colour:True	1972-1982	16	150	20	67.8
Hardness:total	1972-1982	33	138	17.5	51.8
calcium	1972-1982	33	21.5	4.5	11.1
magnesium	1972-1982	33	20.6	1.53	5.97
Metals: (total)					
Aluminum	1982-1983	6	1.39	0.27	0.76
Cadmium	1982-1983	6	< 0.01	< 0.01	< 0.01
Chromium	1972-1983	21	< 0.01	< 0.005	< 0.005+
Copper	1972-1983	37	0.03	< 0.001	0.004+
Iron	1973-1982	36	6.5	0.6	1.7
Lead	1972-1983	39	< 0.1	< 0.001	0.004+
Manganese	1972-1982	37	0.6	0.04	0.14
Molybdenum	1975-1983	7	< 0.02	0.0027	< 0.01+
Zinc	1972-1983	39	0.05	< 0.005	0.015
Nitrogen:					
Ammonia	1974-1983	52	0.582	0.006	0.215
Nitrate	1976-1983	43	2.3	0.14	0.82
Nitrite	1972-1983	61	0.048	0.005	0.021
nitrate/nitrite	1976-1983	43	2.32	0.17	0.84
Kjeldahl	1972-1983	50	4	0.38	1.22
Organic	1973-1983	49	3.95	0.45	1.01
Oil and Grease	1981	3	4.6	1.1	2.6
Oxygen: BOD_5	1981	3	< 10.	< 10	< 10
dissolved	1972-1983	48	16.7	1.1	8.2
COD	1981-1983	28	71	13	33.1
% Saturation	1972-1983	48	167.8	9.7	74.1
Phenol	1982	3	0.008	0.002	0.005
pH	1972-1983	58	7.8	6.3	7.0+
Phosphorus:ortho-diss.	1973-1983	55	0.261	0.02	0.099
total diss.	1976-1983	40	0.291	0.036	0.127
total	1972-1983	36	0.552	0.074	0.196
Potassium:Dissolved	1972-1983	37	5.9	1.6	3.0
Silica	1972-1982	7	20	8.4	15.6
Sodium:Dissolved	1972-1983	37	146	6.8	26
Solids:Suspended	1974-1983	44	84	7	26
Dissolved	1972-1978	24	490	98	173
total	1972-1983	39	730	68	218
Specific Conductivity	1972-1983	58	1170	63	261
Sulphate	1972-1983	38	110	7.2	22.5
Temperature	1972-1983	48	21	1	10.2
Tannin/Lignin	1974-1981	8	3.2	1.4	2.2
Turbidity	1972-1983	9	17	4.7	9.4

* All values are as mg/L except
(1) Coliforms as MPN/100 mL (2) Colour as colour units (3) pH
(4) Temperature as °C (5) Specific Conductivity as μS/cm

+ Median Value
Data Source: Ministry of Environment and Parks

TABLE 11(a) (Continued)

Constituent	Site 1100041 Serpentine River at 88 Ave				
	Period of Record	No. of Values	Values*		
			Maximum	Minimum	Mean
Carbon: - Organic	1981	2	17	17	17
- Inorganic	1981	2	22	22	22
Chloride	1981	2	47	47	47
Coliform: fecal	1981	4	490	230	460 +
Colour: True	1981	2	80	80	80
Nitrogen:					
Ammonia	1981	2	0.288	0.288	0.288
Nitrate	1981	2	0.76	0.76	0.76
Nitrite	1981	2	0.025	0.025	0.025
Organic	1981	2	2.	2	2
Nitrate/Nitrite	1981	2	0.79	0.79	0.79
Kjeldahl	1981	2	2	2	2
Oxygen: BOD_5	1981	2	< 10	< 10	<10
COD	1981	2	62	62	62
pH	1981	2	6.9	6.9	6.9+
Phosphorus:ortho-Diss.	1981	2	0.097	0.097	0.097
total	1981	2	0.376	0.376	0.376
Potassium	1981	2	4	4	4
Silica	1981	2	18.1	18.1	18.1
Sodium	1981	2	39	39	39
Solids: Dissolved	1981	2	251	251	251
Suspended	1981	2	85	85	85
total	1981	2	336	336	336
Specific Conductivity	1981	2	399	399	399
Sulphate	1981	2	49.2	49.2	49.2
Tannin & Lignin	1981	2	2.5	2.5	2.5

* All values are as mg/L except:
(1) Coliform as MPN/100 mL (2) pH (3) Temperature as °C
(5) Turbidity as N.T.U. (6) Specifc Conductivity as µS/cm
+ Median value
Data Source: Ministry of Environment and Parks

TABLE 11(a) Continued

Constituent	Site 1100037 Serpentine River at 168 St.				
	Period of Record	No. of Values	Values*		
			Maximum	Minimum	Mean
Alkalinity: total	1975-1978	7	9.7	0.8	4.8
Arsenic:Total	1974	2	< 0.005	< 0.005	< 0.005
Boron	1974-1979	21	< 0.1	< 0.1	< 0.1
Carbon: Organic	1974-1981	25	21	< 1	5.4
Inorganic	1981	3	18	11	15
Chloride: dissolved	1974-1981	34	30.4	3.3	7.7
Coliforms: fecal	1979-1981	11	3500	130	872 +
Colour True	1976-1981	15	120	5	29
Fluoride	1976	1	< 0.1	-	-
Hardness:total	1974-1979	18	51.4	9.17	36.9
calcium	1974-1979	38	14	2.9	9.6
magnesium	1974-1981	38	4.2	0.6	2.8
Metals: (Total)					
Cadmium	1974-1975	16	0.009	< 0.0005	0.0005
Chromium	1974	2	< 0.005	< 0.005	< 0.005
Copper	1974-1979	8	0.007	< 0.001	0.003
Iron	1979	31	4.2	0.1	0.65
Lead	1974-1979	22	0.044	< 0.001	0.007
Manganese	1974-1975	16	0.07	< 0.02	0.031
Mercury	1974-1975	16	< 0.0005	< 0.0005	< 0.0005
Nickel	1974	1	< 0.01	-	-
Zinc	1974-1979	22	0.11	< 0.005	0.015
Nitrogen:Ammonia	1976-1981	16	0.234	0.01	0.0575
Nitrate/Nitrite	1974-1979	42	3.25	0.03	0.527
Nitrate	1981	3	0.71	0.65	0.68
Nitrite	1981	4	0.022	0.016	0.021
Organic	1978-1981	6	1.03	0.14	0.501
Kjeldahl	1974-1981	40	1.26	0.11	0.323
Oxygen: BOD_5	1981	4	< 10	< 10	< 10
COD	1981	4	53	37	43.8
dissolved	1974-1979	29	14.7	8.1	11.6
% saturation	1974-1979	29	149.1	84.7	111.3
Oil and Grease	1981	1	1.2	-	-
pH	1974-1981	42	9.3	6.7	7.5 +
Phosphorus:ortho diss.	1974-1981	35	0.108	0.008	0.026
total dissolved	1974-1981	37	0.12	0.012	0.035
total	1974-1981	42	0.269	0.022	0.064
Potassium:Dissolved	1974-1981	34	3.7	0.7	1.58
Sodium:Dissolved	1974-1981	34	27.8	3.3	7.71
Solids:total	1979-1981	7	298	84	169
Suspended	1979-1981	7	63	2	20
Dissolved	1979-1981	7	80	258	150
Salinity	1974-1977	4	100	0	25
Silica	1981	3	19.5	16.3	17.6
Sulphate	1974-1981	29	70	< 5	14.6
Specific Conductivity	1974-1981	44	365	41	120
Tannin/Lignin	1981	3	2.3	1.9	2.1
Temperature	1974-1981	33	18.9	3.5	11.7
Turbidity	1974-1981	38	36	1	5.5

* All values are as mg/L except
(1) Coliforms as MPN/100 mL (2) Colour as colour units (3) pH
(4) Temperature as °C (5) Turbidity as N.T.U. (6) Specific Conductivity as µS/cm
(7) % saturation as %

+ Median value
Data Source: Ministry of Environment and Parks

TABLE 11 (b)

SEDIMENT CHEMISTRY DATA SUMMARY, SERPENTINE RIVER

Constituent	Site 0300057			
	Period of Record	No. of Values	Values	
			Maximum	Minimum
Arsenic*	1982	1	< 25	-
Carbon: Organic+	1982	2	8.1	6.0
Inorganic+	1982	1	17	-
Metals:				
Aluminum+	1982	1	6.89	-
Boron*	1982	1	< 1	-
Barium+	1982	1	0.029	-
Beryllium*	1982	1	< 1	-
Cadmium+	1982	1	< 0.001	-
Calcium+	1982	1	3.25	-
Chromium+	1982	1	0.031	-
Cobalt+	1982	1	0.012	-
Copper+	1982	1	0.021	-
Iron+	1982	1	18.1	-
Lead+	1982	1	0.058	-
Magnesium+	1982	1	5.61	-
Manganese+	1982	1	0.182	-
Molybdenum*	1982	1	7	-
Nickel+	1982	1	0.038	-
Selenium*	1982	1	< 10	-
Strontium*	1982	1	29	-
Tellurium*	1982	1	< 20	-
Thallium*	1982	1	< 20	-
Tin*	1982	1	< 5	-
Titanium+	1982	1	0.19	-
Vanadium*	1982	1	26	-
Zinc+	1982	1	0.089	-
Nitrogen: Kjeldahl+	1982	2	2	1.463
Phosphorus:total+	1982	2	0.801	0.463
Organic Component+	1982	2	5	1.92

Data Source: Ministry of Environment and Parks

+ Sample Unit = mg/g dry weight

* Sample Unit = µg/g dry weight

TABLE 11(b) (Continued)

Constituent	Site 1100034 Serpentine River at Hwy 99			
	Period of Record	No. of Values	Values	
			Maximum	Minimum
Arsenic*	1979	2	10	6
Metals:				
Aluminum+	1979	1	8.69	-
Barium+	1979	1	0.023	-
Cobalt+	1979	1	0.015	-
Calcium+	1979	2	3.15	2.7
Cadmium+	1979	2	< 0.001	< 0.001
Chromium+	1979	2	0.032	0.024
Copper+	1979	2	0.021	0.015
Iron+	1979	2	19.4	19.3
Lead+	1979	2	0.023	0.019
Magnesium+	1979	2	6.31	6.27
Manganese+	1979	2	0.201	0.161
Molybdenum*	1979	2	2	< 1
Nickel+	1979	2	0.025	0.025
Strontium*	1979	1	27	-
Titanium+	1979	1	0.276	-
Vanadium*	1979	1	24	-
Zinc+	1979	2	0.048	0.042
Nitrogen:				
Kjeldahl+	1979	2	1.09	1.09
Phosphorus:total+				

Data Source: Ministry of Environment and Parks
+ Unit = mg/g dry weight
* Unit = µg/g dry weight

TABLE 11(b) Continued

Constituent	Site 1100035 Serpentine River at Hwy 10			
	Period of Record	No. of Values	Values	
			Maximum	Minimum
Arsenic*	1979	2	14	< 5
Metals: dissolved				
Aluminum+	1979	1	9.11	-
Antimony+	1979	1	0.015	-
Barium+	1979	1	0.036	-
Cadmium+	1979	2	< 0.001	< 0.001
Calcium+	1979	2	4.47	2.75
Chromium+	1979	2	0.036	0.014
Cobalt+	1979	1	0.016	-
Copper+	1979	2	0.026	0.013
Iron+	1979	2	26.7	15.2
Lead+	1979	2	0.053	0.04
Magnesium+	1979	2	7.15	4.52
Manganese+	1979	2	0.52	0.256
Molybdenum+	1979	2	2	< 1
Nickel+	1979	2	0.045	0.038
Strontium*	1979	1	13	-
Titanium+	1979	1	0.482	-
Vanadium*	1979	1	25	-
Zinc+	1979	2	0.095	0.095
Nitrogen: Kjeldahl+	1979	2	2.79	2.52
Phosphorus:total+	1979	2	1.04	0.303

Data Source: Ministry of Environment and Parks

+ Unit = mg/g dry weight

* Unit = µg/g dry weight

TABLE 11(b) Continued

Constituent	Site 1100036 Serpentine River at 80 Ave			
	Period of Record	No. of Values	Values	
			Maximum	Minimum
Arsenic*	1979	2	15	< 5
Metals:				
Aluminum+	1979	1	10.9	-
Antimony+	1979	1	0.013	-
Barium+	1979	1	0.061	-
Cadmium+	1979	2	< 0.001	< 0.001
Calcium+	1979	2	4.26	2.78
Chromium+	1979	2	0.043	0.043
Cobalt+	1979	1	0.017	-
Copper+	1979	2	0.03	0.015
Iron+	1979	2	29.0	19.1
Lead+	1979	2	0.041	0.037
Magnesium+	1979	2	8.49	5.34
Manganese+	1979	2	0.361	0.274
Molybdenum*	1979	2	2	< 1
Nickel+	1979	2	0.037	0.017
Strontium*	1979	1	16	-
Titanium+	1979	1	0.438	-
Vanadium*	1979	2	31	31
Zinc+	1979	2	0.08	0.049
Nitrogen: Kjeldahl+	1979	2	1.79	0.82
Phosphorus:total+	1979	2	0.774	0.467

Data Source: Ministry of Environment and Parks
+ Unit = mg/g dry weight
* Unit = μg/g dry weight

TABLE 11(b) Continued

Constituent	Site 0300059 Serpentine River at 80 Ave		Site 1100044 Serpentine River at 104 Ave	
	Period of Record	Values**	Period of Record	Values**
Arsenic*	1982	29	1979	12
Boron+	1982	< 1	-	-
Carbon: Organic+	1982	63	-	-
Inorganic+	1982	70	-	-
Metals:				
Aluminum+	1982	11.8	-	-
Barium+	1982	0.081	-	-
Bryllium*	1982	< 1	-	-
Cadmium+	1982	< 0.001	1979	<0.001
Calcium+	1982	6.9	1979	2.58
Chromium+	1982	0.031	1979	0.019
Cobalt+	1982	0.014	-	-
Copper+	1982	0.041	1979	0.012
Iron+	1982	19.5	1979	16.4
Lead+	1982	0.098	1979	0.071
Magnesium+	1982	4.23	1979	4.61
Manganese+	1982	0.379	1979	0.478
Molybdenum*	1982	10.	1979	1
Nickel+	1982	0.034	1979	0.015
Selenium*	1982	12	-	-
Strontium*	1982	45	-	-
Telurium*	1982	< 20	-	-
Thallium*	1982	< 20	-	-
Tin*	1982	< 5	-	-
Titanium	1982	0.229	-	-
Vanadium*	1982	33	-	-
Zinc+	1982	0.139	1979	0.078
Nitrogen: Kjeldahl+	1982	5.6	1979	0.31
Phosphorus: total+	1982	1.49	1979	0.359

Data Source: Ministry of Environment
+ Unit = mg/g dry weight
* Unit = µg/g dry weight

** n=1

TABLE 11(c)

COMPARISON OF SERPENTINE RIVER SEDIMENT DATA+ WITH OTHER B. C. SITES

Constituent	Serpentine River (Table 11b)	Fraser River[21] (Main Arm)	Sediment Cores From B.C. Lakes[22]	Accumulated Stormwater Sediments - Urban[24]
Cadmium	<0.001	0.0065- 0.007	0.001- 0.011	<0.001- 0.019
Cobalt	0.012- 0.017	0.016 - 0.026	0.010- 0.063	
Copper	0.012- 0.041	0.018 - 0.026	0.004- 0.468	0.022- 0.029
Iron	15.2 -29.0	12.8 -16.7	2.30 -121.00	11.0 -13.4
Lead	0.019- 0.098	0.004 - 0.008	0.010- 0.560	0.160- 0.209
Manganese	0.161- 0.520	0.308 - 0.328	0.016- 9.96	0.195- 0.210
Nickel	0.015- 0.045	0.035 - 0.050	0.005- 0.134	
Zinc	0.039- 0.139	0.028 - 0.047	0.009- 1.06	0.101- 0.183

+ Unit = mg/g dry weight

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[21] D. Stancil. Fraser River Estuary Study, Water Quality. Aquatic Biota and Sediments. December 1980

[22] C. McKean. Ministry of Environment and Parks (unpublished)

[24] L. Swain. Stormwater Monitoring of a Residential Catchment Area: Vancouver, B. C. Water Management Branch, Victoria, B. C. Internal Report. June 1983.

TABLE 12
WATER QUALITY DATA SUMMARY
HYLAND CREEK (SITE 9)

Constituent	Period of Record	No. of Values	Values*		
			Maximum	Minimum	Mean
CARBON: Organic	1981	2	7	6	6.5
Inorganic	1981	2	18	18	18
Coliforms: fecal	1981	4	3500	2800	3500 +
Colour:True	1981	4	40	20	30
Chloride: dissolved	1981	1	15.9	-	-
Metals: (total)					
Copper	1981	1	0.002	-	-
Iron	1981	1	1	-	-
Lead	1981	1	0.006	-	-
Zinc	1981	1	0.005	-	-
Nitrogen:Ammonia	1981	4	0.058	0.016	0.031
Nitrate	1981	3	0.79	0.57	0.69
Nitrite	1981	3	0.011	0.007	0.009
Oil and Grease	1981	1	2.1	-	-
Oxygen: BOD_5	1981	1	< 10	-	-
COD	1981	4	22	12.2	17.8
dissolved	1981	4	10.8	8.5	9.4
pH	1981	4	[illegible]	7.4	7.6+
Phosphorus:dissolved	1981	3	0.045	0.038	0.043
Ortho-Diss.	1981	3	0.034	0.029	0.03
total	1981	2	0.071	0.069	0.070
Potassium:dissolved	1981	1	1.9	-	-
Sodium:dissolved	1981	1	13.2	-	-
Solids:total	1981	3	156	132	144
Suspended	1981	3	18	3	9.3
Silica:Reactive	1981	1	14.9	-	-
Sulphate Dissolved	1981	2	6.7	6.7	6.7
Specific Conductivity	1981	4	193	181	188
Tannin/Lignin	1981	4	1	0.7	0.8
Temperature	1981	4	15.9	13	14.5
Turbidity	1981	1	3.8	-	-

* All values are as mg/L except:
(1) Coliforms as MPN/100 mL (2) Colour as colour units (3) pH
(4) Temperature as °C (5) Specific conductivity as µS/cm (6) Turbidity as NTU
+ Median value

Data Source: Ministry of Environment and Parks

TABLE 13
WATER QUALITY DATA SUMMARY
MAHOOD (BEAR) CREEK

Constituent	Site 1100056				
	Sample Period	No. of Values	Values*		
			Maximum	Minimum	Mean
Alkalinity: total	1974-1979	23	68.1	16.1	43.3
Arsenic	1974-1979	2	0.006	<0.005	-
Boron	1974-1979	20	<0.1	<0.1	<0.1
Carbon: Organic	1974-1979	21	18	1	6.1
Chloride: Dissolved	1974-1979	29	13.2	3.7	6.7
Coliforms: total	1979	1	920	-	-
Colour:True	1976-1979	15	40	10	21
Hardness:total	1976-1979	18	64.7	23.7	48.9
calcium	1974-1979	38	16.9	6.2	12.2
magnesium	1974-1979	38	5.7	1.4	3.7
Metals: (total)					
Cadmium	1974-1979	16	<0.0005	<0.0005	<0.0005
Chromium	1974	2	0.006	<0.005	-
Copper	1974,1979	9	0.007	<0.001	0.003
Iron	1974-1979	32	9.5	0.5	1.47
Lead	1974,1979	23	0.054	<0.001	0.006
Manganese	1974-1979	15	0.18	<0.02	0.059
Mercury	1974-1979	17	0.00006	<0.00005	0.00005
Zinc	1974-1979	23	0.12	<0.005	0.014
Nitrogen:Ammonia	1976-1979	14	0.117	0.009	0.051
Nitrate/Nitrite	1974-1979	39	3.45	0.51	1.1
Organic	1978-1979	5	0.98	0.25	0.58
Kjeldahl	1974-1979	39	1.35	0.08	0.42
Total	1976-1979	10	4.32	1.13	1.82
Oxygen: dissolved	1974-1979	29	13.4	7.5	10.3
% saturation	1974-1979	29	135.2	76.3	97.4
pH	1974-1979	39	8.1	6.9	7.6+
Phosphorus:ortho	1974-1979	31	0.36	0.009	0.019
total dissolved	1974-1979	32	0.049	0.014	0.027
total	1974-1979	39	0.273	0.024	0.064
Potassium dissolved	1974-1979	29	3.3	0.9	1.71
Sodium dissolved	1974-1979	29	10.9	3.5	6.43
Solids: Total	1974-1979	2	98	84	91
Dissolved	1974-1979	2	76	71	73.5
Suspended	1974-1979	3	22	4	13
Specific Conductivity	1974-1979	27	1100	45	138
Temperature	1974-1979	35	17.5	[illegible].7	11.5
Turbidity	1974-1979	39	104	2.2	14.2

* All values are as mg/L except:
(1) Coliforms as MPN/100 mL (2) Colour as colour units (3) pH
(4) Temperature as °C (5) Specific Conductivity as µS/cm (6) Turbidity as NTU
(7) % saturation as %

+ Median value

Data Source: Ministry of Environment and Parks

TABLE 13 Continued

Constituent	Site 0300056				
	Sample Period	No. of Values	Values*		
			Maximum	Minimum	Mean
Alkalinity:total	1972-1983	39	66.3	19.8	43.3
Arsenic	1982	6	<0.25	<0.005	-
Boron: dissolved	1972	3	<0.2	<0.1	<0.1+
Carbon: Organic	1981-1982	7	7	1	3.14
Inorganic	1981-1983	7	17	15	16
Coliforms:total	1972-1976	19	>2400	330	2400 +
fecal	1973-1983	42	16000	20	490 +
Chloride: dissolved	1972-1983	40	151	2.8	10.7
Colour True	1972-1982	13	40.	10	20.8
Hardness:total	1972-1982	30	63.9	24.4	45.4
calcium	1972-1982	30	17.3	7.3	12.3
magnesium	1972-1982	30	5.7	1.5	3.6
Metals: (total)					
Aluminum	1982-1983	5	0.58	0.06	0.21
Cadmium	1982-1983	5	<0.01	<0.01	<0.01
Chromium	1972-1983	20	0.013	<0.005	<0.005+
Copper	1972-1983	34	0.02	<0.001	0.003+
Iron	1973-1983	33	11.	0.32	1.48
Lead	1972-1983	36	<0.1	<0.001	0.004+
Manganese	1972-1983	33	0.8	0.03	0.09
Molybdenum	1982-1983	6	0.01	0.0016	<0.01+
Zinc	1972-1983	35	0.044	<0.005	0.014
Nitrogen:Ammonia	1972-1983	38	0.38	0.008	0.063
Nitrate/Nitrite	1976-1983	29	1.47	0.52	1.
Nitrate	1972-1983	29	1.46	0.51	0.99
Nitrite	1972-1983	46	0.029	0.005	0.013
Organic	1973-1982	33	0.89	0.13	0.30
Kjeldahl	1972-1983	37	1.02	0.15	0.41
Oil and Grease	1981	1	1.6	-	-
Oxygen: BOD$_5$	1981	1	<10	-	-
COD	1981-1982	10	16.7	<10	11.42
Dissolved	1974-1983	36	13.4	8.5	10.9
% Saturation	1974-1983	36	131	83.4	98.1
pH	1972-1983	44	8.0	6.8	7.4 +
Phosphorus:ortho-diss.	1973-1983	43	0.056	0.01	0.02
Total dissolved	1976-1983	28	0.062	0.016	0.03
Total	1972-1982	31	0.183	0.027	0.052
Potassium:dissolved	1972-1983	36	3.4	1.3	1.8
Phenol	1982	4	0.006	<0.002	0.003
Sodium:dissolved	1973-1983	36	89	3.2	9.1
Solids:total	1972-1983	28	190	71	113
dissolved	1972-1977	23	338	68	106
Suspended	1974-1983	37	129	1	17
Silica: Reactive	1972-1982	5	17.9	8.9	14.4
Sulphate	1972-1982	37	12.6	<5	7.2
Specific Conductivity	1972-1983	43	609	73	148
Tannin/Lignin	1975-1982	6	0.6	0.3	0.5
Temperature	1972-1983	36	19	1.1	9.7
Turbidity	1972-1975	6	11	3.4	5.7

* All values are as mg/L except
(1) Coliforms as MPN/100 mL (2) Colour as colour units (3) pH
(4) Temperature as °C (5) Specific Conductivity as µS/cm (6) Turbidity as N.T.U.
(7) % saturation as %
+ Median value
Data Source: Ministry of Environment and Parks

TABLE 14
WATER QUALITY DATA SUMMARY
LATIMER CREEK
SITE 8

Constituent	Sample Period	No. of Values	Values*		
			Maximum	Minimum	Mean
Carbon: Organic	1981	3	8	6	6.7
Inorganic	1981	3	14	13	13.7
Chloride: dissolved	1981	2	51.2	35.4	43.3
Coliforms: fecal	1981	5	5400	790	3500 +
Colour:True	1981	5	60	40	36
Metals: (total)					
Copper	1981	1	0.002	-	-
Iron	1981	1	1.2	-	-
Lead	1981	1	0.003	-	-
Zinc	1981	1	<0.005	-	-
Nitrogen:Ammonia	1981	5	0.161	0.06	0.087
Unionized Ammonia	1981	5	0.00069	0.00024	0.00049
Nitrate	1981	4	1.99	1.6	1.77
Nitrite	1981	4	0.027	0.016	0.02
Oil and Grease	1981	2	1.7	1.4	1.55
Oxygen: BOD_5	1981	2	<10	<10.	<10
COD	1981	5	28	12.7	18.6
dissolved	1981	5	9.5	7.8	8.4
pH	1981	5	7.6	7.1	7.3 +
Phosphorus:Ortho-Diss.	1981	4	0.038	0.021	0.029
total dissolved	1981	4	0.051	0.037	0.043
total	1981	3	0.089	0.069	0.082
Potassium:dissolved	1981	2	2.4	2.2	2.3
Sodium:dissolved	1981	1	26.8	-	-
Solids:total	1981	4	200	160	178
Suspended	1981	4	14	5	9
Dissolved	1981	4	177	153	169
Silica: Reactive	1981	2	12.3	11.6	11.95
Specific Conductivity	1981	5	295	225	248
Sulphate dissolved	1981	3	5.8	5	5.27
Tannin/Lignin	1981	5	1.7	1.2	1.32
Temperature	1981	5	22.5	12.5	15.8
Turbidity	1981	1	7.3	-	-

* All values are as mg/L except:
(1) Coliforms as MPN/100 mL (2) pH (3) Colour as colour units
(4) Turbidity as N.T.U. (5) Specific Conductivity as µS/cm
+ Median value
Data Source: Ministry of Environment and Parks

TABLE 14 Continued

CONSTITUENT*	SITE+									
	A		B		C	D	E	F	G	H
Coliform: Fecal	480	80	2400	1300	230	790	230	140	1300	330
Nitrogen:										
Ammonia	0.045	0.59	0.061	0.018	0.023	0.023	0.64	0.009		0.06
Un-ionized Ammonia	0.0001	0.0021	0.0002	0.0002	0.0001	0.0009	0.011	0.0001		0.0001
Nitrate										1.49
Nitrite										0.049
Organic	0.62	3	0.33	0.87	0.29	0.16	0.61	0.17	0.47	0.011
Kjeldahl	0.66	4	0.39	0.89	0.31	0.18	1.25	0.18	0.48	
Oxygen:Dissolved	6.8	5.6	8.6	8.8	9.6	7.4	9.2	9.6	8.9	7.6
pH	7.1	6.9	7.1	7.5	7.1	8.1	7.7	7.7	7.4	6.7
Phosphorus: Ortho-Diss	0.072	0.031	0.026	0.072	0.009	0.167	0.054	0.132	0.059	0.015
Specific Conductivity	181	429	191	214	146	210	172	172	124	162
Tannin & Lignin	1.8	2.2	1.1	0.9	0.5	0.4	0.7	0.6	0.9	0.9
Temperature	17.8	21.5	15.9	21.5	14.0	18.4	18.2	15.4	16.1	15.
Turbidity	5.5		5.1		2.2	5.5	3	1.8	6.4	5.3

* All values are as mg/L except:
(1) pH (2) Temperature as °C (3) Specific conductivity as µS/cm
(4) Coliforms as MPN/100 mL (5) Turbidity as N.T.U.

Data Source: Ministry of Environment and Parks

+ Samples collected on 23 July 1981 appear in the first column for each site while samples collected on 11 August 1981 appear in the second column for sites A and B.

TABLE 15
ESCAPEMENT VALUES FOR THE NICOMEKL RIVER

YEAR	COHO	STEELHEAD
1947	1500	
1948	1500	
1949	1500	
1950	1500	
1951	1500	75
1952	3500	
1953	3500	
1954	3500	
1955	1500	
1956	1500	75
1957	750	
1958	750	
1959	750	
1960	750	
1961	3500	
1962	200	
1963	200	
1964	7500	
1965	200	
1966	400	
1967	400	
1968	200	
1969	75	
1970	1500	
1971	3500	
1972	1500	
1973	3500	
1974	2500	
1975	3500	
1976	3500	
1977	3400	
1978	1500	
1979	1500	
1980	1750	
1981	1000	
1982	1200	
1983	1000	

TIMING OF SPAWNING:

ARRIVE	September
START	Early November
PEAK	Late November
END	Late December

Data From: Hancock, M.J. and D.E. Marshall. 1985. Catalogue of Salmon Streams and Spawning Escapements of Statistical Area 29. Canadian Data Report of Fisheries and Aquatic Science No. 495. Department of Fisheries and Oceans.

TABLE 16
EFFLUENT DATA SUMMARY
AMBASSADOR INDUSTRIES LTD. LANGLEY PE 5269

CONSTITUENT	PERIOD OF RECORD	NO. OF VALUES	VALUES*	
			MAXIMUM	MINIMUM
Nitrogen: ammonia	1980	1	0.86	-
nitrate/nitrite	1980	1	5.9	-
nitrate	1980	1	5.89	-
nitrite	1980	1	0.005	-
Oxygen : BOD$_5$	1980,1982	2	469	299
dissolved	1980	1	7.7	-
pH	1980,1982	2	7.2	6.7^{+}
Phosphorus: ortho-dissolved	1980	1	2.02	-
total	1980	1	2.10	-
Solids: Total	1980-1982	2	826	650
Specific Conductivity	1980,1982	2	535	255
Temperature	1980	1	20.5	-

* All values are as mg/L except:
(1) pH (2) Specific Conductivity as µS/cm
(3) Temperature as °C
Data Source: Ministry of Environment and Parks

TABLE 17
EFFLUENT DATA SUMMARY
WESTERN PAVING LIMITED (PE 2367)

Constituent	Period of Record	No. of Values	Values*		
			Maximum	Minimum	Mean
Coliform:fecal	1974	1	5	-	-
total	1974	1	21	-	-
Flow	1974-1978	45	1 145.6	110.47	830.32
pH	1974-1978	8	8.3	6.7	7.55+
Specific Conductivity	1974-1978	9	168	90	132
Solids					
Total	1974-1978	13	64 183	3	11 599
Dissolved	1978	1	90	-	-
Suspended	1974-1978	13	64 268	74	12 190

* All values are as mg/L except (1) Coliform as MPN/100 mL
(2) pH (3) Specific Conductivity as µS/cm,
(4) Flow as m^3/d.

+ Median
Data Source: Ministry of Environment and Parks

TABLE 18
EFFLUENT DATA SUMMARY
SURREY CO-OPERATIVE ASSOCIATION
SITE PE 4262

Constituent	Sample Period	No. of Values	Values*		
			Maximum	Minimum	Mean
Flow	1983	1	0.0065	-	-
Oil and Grease 1.	1976-1978	4	168	2.9	49.3
2.	1976-1979	4	14	1	6.3
3.	1983-1984	6	90	0	50.3
4.	1984	1	26.6	-	-
pH 1.	1977	2	7.1	7	7.05
3.	1983	1	7	-	-
4.	1984	1	7.18	-	-
Suspended Solids 1.	1977	2	67	45	56
3.	1983	1	8	-	-
4.	1984	1	27	-	-
Specific Conductivity 1.	1977	2	287	202	245

* All values are as mg/L except:
(1) Flow in m^3/d (2) pH (3) Specific Conductivity as µS/cm

Analyses by:
1. Ministry of Environment and Parks
2. Chemex Labs Ltd.
3. Preventive Maintenance Methods Ltd.
4. Analyses by Central Technical Services Ltd.

TABLE 19
WATER QUALITY DATA SUMMARY
NICOMEKL RIVER

SITE 1100002: NICOMEKL RIVER AT DAM

Constituent	Period of Record	No. of Values	Values*		
			Maximum	Minimum	Mean
Alkalinity: total	1974-1979	39	104	22	76.6
Boron: dissolved	1974-1979	41	3.7	0.2	1.9
Chloride	1974-1979	53	14 800	208	9144
Colour:True	1976-1979	22	100	5	33
Hardness: total	1976-1979	29	4 280	60	2180
calcium	1974-1979	71	312	17	185.5
magnesium	1974-1979	69	991	9	592
Nitrogen:					
Ammonia	1976-1979	20	0.13	<0.01	<0.01^{+}
Unionized Ammonia	1976-1977	7	0.0023	0.004	0.0012
Organic	1978-1979	9	2.0	0.3	0.48
Total	1974-1979	20	5	0.35	1.25
Nitrate/Nitrite	1974-1979	71	3.2	<0.02	0.476
Kjeldahl	1974-1979	71	2	<0.01	0.52
Oxygen: dissolved	1972-1979	52	22.5	2.5	9.6
% Saturation	1972-1979	52	253.1	28.5	99.6
pH	1974-1979	71	8.9	6.6	7.6^{+}
Phosphorus:ortho diss.	1974-1979	56	0.164	<0.003	0.054
total diss.	1974-1979	62	0.215	0.01	0.072
Potassium	1974-1979	58	304	8.5	187
Salinity	1974-1979	43	23 100	400	15 666
Sodium	1974-1979	49	8 100	123	5198
Solids:					
Suspended	1976-1979	5	27	9	15
dissolved	1976-1979	4	15 985	2859	14 330
Total	1976-1979	4	23 600	2886	15 846
Specific Conductivity	1974-1979	75	40 800	452	23 725
Sulphate	1974-1979	48	1 975	53.7	1 296
Temperature	1974-1979	59	25	3.9	15.1
Turbidity	1974-1979	71	39	1.9	7.5

+ Median

* All values are as mg/L except (1) colour as relative units ,
(2) pH (3) Termperature as °C,
(4) Specific Conductivity µS/cm, (5) Turbidity as N.T.U.,
(6) Salinity 0/00 (7) % Saturation as %

Data Source: Ministry of Environment and Parks

TABLE 19 Continued

SITE 0300060: NICOMEKL RIVER KING GEORGE HIGHWAY

Constituent	Period of Record	No. of Values	Values* Maximum	Minimum	Mean
Alkalinity:total	1972-1983	47	81.7	18	50.6
Arsenic	1975-1983	9	<0.25	<0.005	-
Carbon:organic	1982-1983	12	18	2	7
inorganic	1982	8	21	12	18.5
Chloride	1972-1983	41	9800	10.3	762
Coliform fecal	1973-1983	38	9200	<2	95+
Colour:True	1972-1982	11	200	20	65.5
Cobalt	1982	6	<0.1	<0.1	<0.1
Hardness:total	1972-1983	38	2342	32.1	251
calcium	1972-1982	32	155	7.9	27.9
magnesium	1972-1983	42	475	3.0	44.5
Metals:total					
Aluminum	1977-1983	8	1.44	0.18	0.44
Cadmium	1982-1983	7	<0.01	<0.01	<0.01
Chromium	1972-1983	31	0.016	<0.005	<0.005+
Copper	1972-1983	34	0.03	<0.001	0.006
Iron	1973-1983	36	3.4	0.14	1.27
Lead	1972-1983	35	<0.1	<0.001	0.003+
Manganese	1979-1983	12	0.16	0.02	0.08
Molybdenum	1982-1983	76	0.01	<0.01	<0.01
Nickel	1972-1983	27	<0.05	<0.01	<0.01+
Zinc	1972-1983	38	0.04	<0.005	0.016
Nitrogen					
nitrate/nitrite	1974-1983	31	4.85	0.24	1.54
Kjeldahl	1974-1983	41	3	0.34	1.18
Ammonia	1974-1983	38	0.428	<0.005	0.127
Un-ionized Ammonia	1974-1983	38	0.0226	0.00023	0.0026
Nitrate	1976-1983	31	4.82	0.22	1.51
Nitrite	1972-1983	48	0.127	<0.005	0.027
Organic	1973-1983	39	2	0.33	0.94
Oxygen					
dissolved	1972-1983	46	17.9	1.3	10.2
COD	1982-1983	13	49	<10	26.8
% saturation	1972-1983	46	188.5	12.7	98.8
pH	1972-1983	44	9.3	6.5	7.2 +
Phenol	1982	4	0.002	<0.002	0.002
Phosphorus					
ortho diss.	1974-1983	45	0.324	<0.003	0.073
total diss.	1976-1983	31	0.249	0.018	0.085
Potassium:Dissolved	1972-1983	37	47	1.9	7.43
Silica	1982	2	0.154	0.052	-
Sodium:Dissolved	1972-1983	37	5500	8.7	276
Solids:					
Suspended	1974-1983	39	60	3	18
Dissolved	1979-1982	12	688	98	268
Total	1972-1983	29	10700	118	1032
Specific Conductivity	1972-1983	45	21250	117	1373
Sulphate	1972-1983	36	323	10.5	61.5
Temperature	1972-1983	46	25	1.9	12.3
Turbidity	1972-1975	6	35	3.4	13.5

+ Median

* All values are as mg/L except (1) Coliform as MPN/100 mL (2) Colour as Colour units, (3) pH (4) Temperature as °C
(5) Turbidity as N.T.U. (6) Specific Conductivity as µS/cm
(7) % Saturation as %

Data Source: Ministry of Environment and Parks.

TABLE 19 Continued

SITE 1100003 NICOMEKL RIVER AT HIGHWAY 99

Constituent	Period of Record	No. of Values	Values*		
			Maximum	Minimum	Mean
Alkalinity:total	1974-1979	43	88.2	17.5	54.3
Boron	1974-1979	43	2.4	<0.1	0.75:0.3$^+$
Chloride	1974-1979	54	10300	16	2375
Coliform:total	1979-1983	2	240	140	-
Colour:True	1976-1979	22	150	15	51
Hardness:					
total	1976-1979	29	3780	28.4	364
calcium	1974-1979	69	238	6.6	61.1
magnesium	1974-1979	69	775	2.9	167
Metals:(Total)					
Cadmium	1974-1975	27	0.0014	<0.0005	<0.0005$^+$
Chromium	1974	6	0.009	<0.005	0.006
Copper	1974-1979	16	0.02	0.001	0.006
Iron	1974-1979	54	4.5	0.2	1.05
Lead	1974-1979	37	0.012	0.001	0.003
Manganese	1974-1976	28	0.17	0.03	0.07
Mercury	1974-1975	28	0.0001	<0.00005	<0.00005
Zinc	1974-1979	38	0.11	0.005	0.014
Nitrogen:					
Ammonia	1976-1979	13	0.22	0.012	0.113
Un-ionized Ammonia	1976-1979	11	0.074	0.00007	0.0018
Organic	1978-1979	8	2	0.63	1.02
Nitrate/nitrite	1974-1979	70	3.9	<0.02	0.77
Kjeldahl	1974-1979	70	2.0	<0.01	0.88
Oxygen: dissolved	1974-1979	56	22.5	0.8	11.0
% saturation	1974-1979	56	263.8	8.8	115.4
pH	1974-1979	70	9.2	6.5	7.75
Phosphorus					
ortho-diss.	1974-1979	59	0.322	<0.003	0.055
total diss.	1974-1979	62	0.346	0.011	0.076
Potassium:Dissolved	1974-1979	56	213	2.1	53.7
Solids:					
Suspended	1974-1979	31	68	3	16
Dissolved	1974-1976	16	7367	77	1420
Total	1974-1979	29	11000	146	1448
Sodium: Dissolved	1974-1979	51	5720	13.6	1407
Specific Conductivity	1974-1979	74	30000	109	7885
Sulphate	1974-1979	49	1472	16.3	335.7
Temperature	1974-1979	60	24	3	15.6
Turbidity	1974-1979	68	46	1.2	9.5

+ Median

* All values are as mg/L except (1) Coliform as MPN/100 mL, (2) Colour as colour units, (3) pH (4) Specific Conductivity as μS/cm, (5) Temperature as °C, (6) Turbidity as N.T.U. (7) % saturation as %

Data Source: Ministry of Environment and Parks.

TABLE 19 Continued

SITE 1100004: NICOMEKL RIVER AT 40 AVE

Constituent	Period of Record	No. of Values		Values*	
			Maximum	Minimum	Mean
Alkalinity	1980	5	70.7	43.9	57.6
Colour:True	1980	5	100	40	54
Hardness:total	1980	5	91.5	84.7	89
calcium	1980	5	20.5	18.6	19.5
magnesium	1980	5	10.0	9.3	9.8
Nitrogen:					
Ammonia	1980	5	0.31	0.044	0.14
Un-ionized Ammonia	1980	4	0.004	0.0008	0.0018
Organic	1980	5	2	0.95	1.25
Total	1980	5	3	1.86	2.28
nitrate/nitrite	1980	5	1.42	0.58	1.03
Kjeldahl	1980	5	2	1.06	1.33
pH	1980	12	9.4	6.8	7.4+
Phosphorus:					
ortho-Diss.	1980	5	0.105	0.013	0.044
total	1980	5	0.31	0.092	0.196
Solids:					
Suspended	1980	12	29	7	16
Dissolved	1980	12	274	178	216
Total	1980	12	300	194	232
Specific Conductivity	1980	12	408	259	334
Sulphate	1980	5	55.1	38.2	45.9
Temperature	1980	5	19	3.8	9.2

+ Median

* All values are as mg/L except (1) Colour as colour units, (2) pH (3) Specific Conductivity as µS/cm, (4) Temperature as °C

Data Source: Ministry of Environment and Parks.

TABLE 19 Continued

SITE 1100005: NICOMEKL RIVER AT 168 ST

Constituents	Period of Record	No. of Values	Values*		
			Maximum	Minimum	Mean
Alkalinity:Total	1974-1980	6	72.5	52.3	62.5
Boron: dissolved	1974-1979	21	0.9	<0.1	0.2
Chloride	1974-1979	29	4850	10.1	412
Colour:True	1976-1980	17	150	20	47
Hardness:					
total	1976-1980	20	108	38.1	67.6
calcium	1974-1980	41	118	7.4	19.8
magnesium	1974-1980	41	321	3.2	24.1
Metals (total):					
Cadmium	1974-1975	15	<0.0005	<0.0005	<0.0005
Chromium	1974	2	<0.005	<0.005	<0.005
Copper	1974	5	0.012	0.001	0.005
Iron	1974-1977	25	5	0.5	1.5
Lead	1974-1975	17	0.007	<0.001	<0.001+
Mercury	1974-1975	17	0.00003	<0.00005	<0.00005+
Zinc	1974-1975	17	0.03	<0.005	0.011
Nitrogen:					
Ammonia	1976-1980	16	0.352	0.027	0.141
Un-ionized Ammonia	1976-1980	16	0.0024	0.0002	0.0011
nitrate/nitrite	1974-1980	41	7.0	0.41	1.28
Kjeldahl	1974-1980	41	3.0	0.26	0.94
Oxygen:dissolved	1974-1979	28	16.5	5.4	10.3
% saturation	1974-1979	28	185.8	69.8	106.1
pH	1974-1980	49	8.4	6.4	7.3+
Phosphorus:					
ortho diss.	1974-1980	33	0.394	0.006	0.077
total diss.	1974-1980	36	0.437	0.019	0.096
Potassium:Dissolved	1974-1979	30	101	1.6	10
Sodium:Dissolved	1974-1979	27	2680	8.8	252
Solids:					
Suspended	1974-1980	28	81	4	15
Dissolved	1980	10	302	132	204
Total	1974-1980	26	9796	146	655
Specific Conductivity	1974-1980	51	14800	118	996
Sulphate	1974-1980	28	661	9.9	78.1
Temperature	1974-1980	44	23	3.3	14.3
Turbidity	1974-1980	42	56	2	12.3

+ Median

* All values are as mg/L except (1) Colour as colour units, (2) pH (3) Specific Conductivity as µS/cm, (4) Temperature as °C, (5) Turbidity as N.T.U. (6) % saturation as %.

Data Source: Ministry of Environment and Parks.

TABLE 19 Continued

SITE 1100006: NICOMEKL RIVER AT 192 ST.

Constituent	Period of Record	No. of Values	Values*		
			Maximum	Minimum	Mean
Alkalinity:Total	1974-1979	23	69.3	18.6	50.9
Boron: dissolved	1974-1979	22	<0.1	<0.1	<0.1
Chloride	1974-1979	30	32.3	6.3	20.2
Coliform-fecal	1979	1	130	-	-
-total	1979	1	540	-	-
Colour	1976-1979	15	150	15	40.7
Hardness:					
total	1976-1979	19	63.3	18.8	47
calcium	1974-1979	40	16	4.4	11.4
magnesium	1974-1979	40	6.1	1.9	4.3
Metals:Total					
Cadmium	1972	1	<0.0005	-	-
Copper	1974-1979	5	0.018	0.002	0.008
Iron	1974-1979	17	4.4	0.6	1.5
Lead	1974-1979	7	0.01	<0.001	0.004
Mercury	1974	2	0.00008	<0.00005	-
Zinc	1974-1979	7	0.13	<0.005	0.025
Nitrogen:					
Ammonia	1976-1979	14	0.282	0.018	0.082
Un-ionized Ammonia	1976-1979	14	0.001	0.0001	0.0004
Organic	1978-1979	5	1.0	0.29	0.60
Total	1974-1979	12	4.0	1.1	1.84
nitrate/nitrite	1974-1979	41	2.5	0.5	1.14
Kjeldahl	1974-1979	41	2.0	0.16	0.59
Oxygen: dissolved	1974-1979	31	15.0	8.1	10.7
% saturation	1974-1979	31	134.0	74.0	101.1
pH	1974-1979	41	8.1	6.7	7.4+
Phosphorus:					
ortho diss.	1974-1979	32	0.204	0.029	0.063
total	1974-1979	34	0.228	0.046	0.072
Potassium:Dissolved	1974-1979	31	3	1.5	1.9
Sodium:Dissolved	1974-1979	29	33.3	6.3	19.2
Solids:					
Suspended	1974-1979	27	57	3	13
Dissolved	1978-1979	4	168	132	147
Total	1974-1979	27	176	98	149
Specific Conductivity	1974-1979	43	278	76	188
Sulphate	1974-1979	26	14.7	<5	9.8
Temperature	1974-1979	35	16.5	3.4	11.5
Turbidity	1974-1979	41	46	1.5	8.1

+ Median

* All values are as mg/L except (1) Coliform as MPN/100 mL, (2) Colour as colour units, (3) pH (4) Specific Conductivity as µS/cm, (5) Temperature as °C, (6) Turbidity as N.T.U. (7) % saturation as %.

Data Source: Ministry of Environment and Parks

TABLE 19 Continued
SITE 0300061: NICOMEKL RIVER AT 192 STREET

Constituent	Period of Record	No. of Values	Values*		
			Maximum	Minimum	Mean
Alkalinity:Total	1972-1983	46	77.1	21.5	53.7
Arsenic	1975-1983	10	<0.25	<0.005	-
Carbon:organic	1982-1983	10	4	<1	1.8
inorganic	1982-1983	9	21	19	20
Chloride	1972-1983	43	50	8.2	23.2
Coliform:fecal	1973-1983	45	9200	50	790+
Colour:True	1972-1982	12	50	10	29
Hardness:total	1972-1983	41	80.5	22	50.5
calcium	1972-1983	41	21.5	5.1	12.4
magnesium	1972-1983	45	6.7	2.25	4.8
Metals:Total					
Aluminum	1982-1983	8	0.51	0.06	0.19
Cadmium	1982	7	<0.01	<0.01	<0.01
Chromium	1972-1983	25	0.012	<0.005	0.007
Cobalt	1982	7	<0.1	<0.1	<0.1
Copper	1972-1983	38	0.02	<0.001	0.003+
Iron	1973-1983	39	2.7	0.38	1.06
Lead	1972-1983	31	<0.1	<0.001	<0.001+
Manganese	1979-1983	13	0.27	0.05	0.09
Molybdenum	1982	7	<0.01	<0.01	<0.01
Nickel	1972-1983	30	<0.05	<0.01	<0.01+
Zinc	1972-1983	42	0.025	0.005	0.009
Nitrogen:					
Un-ionized Ammonia	1974-1983	37	0.0012	0.000038	0.0004
nitrate/nitrite	1976-1983	30	2.55	0.97	1.56
Kjeldahl	1972-1983	40	2.0	0.19	0.64
Ammonia	1974-1983	37	0.434	<0.005	0.090
Nitrate	1976-1983	30	2.53	0.95	1.55
Nitrite	1972-1983	47	0.04	<0.005	0.014
Organic	1973-1983	38	2.0	0.17	0.57
Oxygen:					
COD	1982-1983	10	22	<10	13.6
dissolved	1972-1983	43	13.3	7.5	10.5
% saturation	1972-1983	43	158.7	78.7	92.1
pH	1972-1983	43	8.4	7.0	7.4+
Phenol	1982	4	<0.002	<0.002	<0.002
Phosphorus:					
ortho diss.	1973-1983	43	0.099	0.016	0.050
total diss.	1976-1983	30	0.120	0.019	0.060
Potassium:Dissolved	1972-1983	38	3.7	1.5	2.3
Silica	1982	2	17.9	17.6	17.8
Sodium:Dissolved	1972-1983	35	38.2	11.1	21.5
Solids:					
Suspended	1973-1983	35	54	3	14
Dissolved	1972-1983	24	180	74	140
Total	1972-1983	28	190	102	152
Specific Conductivity	1972-1983	44	290	88	215
Sulphate	1972-1983	37	20	5.6	10.7
Temperature	1972-1982	13	23	3.5	9.9
Turbidity	1972-1975	7	17	3.7	10.6

+ Median

* All values are as mg/L except (1) Coliform as MPN/100 mL, (2) Colour as colour units, (3) Specific Conductivity as µS/cm, (4) Temperature as °C (5) Turbidity as N.T.U. (6) pH (7) % saturation as %

Data Source: Ministry of Environment and Parks

TABLE 19 Continued
SITE 0300062: NICOMEKL RIVER AT 64 AVENUE

Constituent	Period of Record	No. of Values	Values* Maximum	Minimum	Mean
Alkalinity	1972-1983	50	65.8	22	47.1
Arsenic	1975-1983	10	<0.25	<0.005	-
Carbon:organic	1982-1983	10	7	2	3.9
inorganic	1982	5	15	14	14.2
Chloride	1972-1983	45	22.9	3	11.3
Coliform:fecal	1973-1983	47	>2400	207	920+
Colour:True	1972-1982	12	55	15	34.2
Hardness:total	1972-1982	43	67.4	24.9	46.3
calcium	1972-1982	43	15.6	5.9	10.9
magnesium	1972-1982	43	8.5	2.4	4.6
Metals:(Total)					
Aluminum	1982	7	0.69	0.14	0.38
Cadmium	1982-1983	8	<0.01	<0.01	<0.01
Chromium	1972-1983	26	0.016	<0.005	<0.005+
Cobalt	1982	7	<0.01	<0.01	<0.01
Copper	1972-1983	30	0.02	<0.001	0.002+
Iron	1973-1983	39	5.5	0.25	1.2
Lead	1972-1982	39	<0.1	<0.001	0.002+
Manganese	1972-1983	37	0.13	0.01	0.04
Molybdenum	1975-1983	9	0.02	0.0005	<0.01+
Nickel	1972-1983	29	<0.05	<0.01	<0.01+
Zinc	1972-1983	34	0.02	<0.005	<0.005
Nitrogen:					
ammonia	1974-1983	40	0.525	<0.005	0.092
un-ionized ammonia	1974-1982	30	0.0017	0.00003	0.0005
nitrate/nitrite	1976-1983	33	3.1	1.29	2.26
nitrite	1972-1983	50	0.034	0.005	0.013
Kjeldahl	1972-1983	43	2.01	0.19	0.71
organic	1973-1983	4	2.0	0.14	0.62
Oxygen:					
COD	1982-1983	11	21	<10	16.3
dissolved	1972-1983	49	14.1	7.8	10.8
% Saturation	1972-1983	49	128.1	71.4	96.9
Phenol	1982	4	<0.002	<0.002	<0.002
pH	1972-1983	46	8.1	6.9	7.5+
Phosphorus:					
ortho diss.	1973-1983	46	0.138	0.026	0.058
total diss.	1976-1983	32	0.175	0.044	0.082
Potassium	1972-1983	39	3.9	0.9	1.8
Sodium	1972-1983	38	21	3.6	13.3
Solids:					
Suspended	1974-1983	41	87	3	19
Dissolved	1972-1978	23	160	70	116
Total	1972-1983	32	226	76	138
Specific Conductivity	1972-1983	46	214	69	165
Sulphate	1972-1983	39	17.6	<5.0	7.5
Temperature	1972-1983	49	19	0.0	9.6
Turbidity	1972-1977	8	56	2.4	12.5

+ Median

* All values are as mg/L except (1) Coliform as MPN/100 mL, (2) Colour as colour units, (3) pH, (4) Specific Conductivity as µS/cm, (5) Temperature as °C, (6) % Saturation as %

Data Source: Ministry of Environment and Parks

TABLE 19 Continued

Site 1100007: NICOMEKL RIVER AT 228 STREET

Constituent	Period of Record	No. of Values	Values*		
			Maximum	Minimum	Mean
Alkalinity:Total	1977-1979	9	51.9	28.2	46.7
Boron:Dissolved	1978-1979	3	<0.1	<0.1	<0.1
Chloride	1978 1979	7	6.4	4.7	5.3
Coliform:fecal	1979	1	240	-	-
total	1979	11	920	-	-
Colour:True	1977-1979	5	80.0	20	49.5
Hardness:					
total	1977-1979	11	60	36.5	47.9
calcium	1977-1979	11	13.3	8.7	11.2
magnesium	1977-1979	11	6.5	3.6	4.8
Metals:Total					
Copper	1979	5	0.016	0.001	0.005
Iron	1979	5	1.80	0.4	0.88
Lead	1979	5	0.003	<0.001	0.0016
Zinc	1979	5	0.11	<0.005	0.027
Nitrogen:					
Ammonia	1977-1979	7	0.185	0.018	0.068
Un-ionized Ammonia	1977-1979	6	0.0006	0.0002	0.0007
Organic	1978-1979	6	1.82	0.038	0.865
Total	1978-1979	10	4.38	1.51	2.58
nitrate/nitrite	1977-1979	11	2.44	0.91	1.92
Kjeldahl	1977-1979	8	2	0.35	0.74
Oxygen: dissolved	1977-1979	8	13	8.7	10.8
% saturation	1977-1979	8	129.7	91.2	105.5
pH	1977-1979	11	7.9	7.2	7.7+
Phosphorus:					
ortho diss.	1977-1979	7	0.141	0.041	0.061
total	1977-1979	7	0.191	0.047	0.082
Potassium	1978-1979	6	3.6	1.1	1.9
Sodium	1978-1979	7	8.3	6	7.4
Solids:					
Suspended	1978-1979	2	28	16	22
dissolved	1978-1979	2	110	86	98
Total	1978-1979	2	126	114	120
Specific Conductivity	1978-1979	8	145	112	135
Sulphate	1978-1979	6	8.3	<5	6.4
Temperature	1977-1979	10	18	5	13.4
Turbidity	1977-1979	11	19	2.2	7.2

+ Median

* All values are as mg/L except (1) Coliform as MPN/100 mL, (2) Colour as colour units, (3) pH, (4) Specific Conductivity as µS/cm, (5) Temperature as °C, (6) Turbidity as NTU, (7) % Saturation as %

Data Source: Ministry of Environment and Parks

TABLE 20
DATA SUMMARY SEDIMENT CHEMISTRY
NICOMEKL RIVER

	VALUES (mg/g dry-weight)							
Constituent	Site 1100007	Site 0300061	Site 1100006	Site 1100005+ Maximum	Minimum	Site 0300060	Site 1100003+ Maximum	Minimum
Arsenic*	16	<25	16	17	15	43	10	<5
Boron*	-	<1	-	-	-	<1	-	-
Calcium	2.82	2.39	2.94	4.23	2.46	4.6	4.24	2.74
Carbon-organic	-	<0.3	-	-	-	26	-	-
-inorganic	-	1.7	-	-	-	10	-	-
METALS:								
Aluminum	-	6.42	-	10.9	-	12.9	7.58	-
Barium	-	0.034	-	0.043	-	0.043	0.038	-
Beryllium*	-	<1	-	-	-	<1	-	-
Cadmium	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Chromium	0.023	0.018	0.023	0.36	0.022	0.052	0.035	0.021
Cobalt	-	<0.01	-	0.022	-	0.017	0.014	-
Copper	0.008	0.011	0.009	0.022	0.02	0.039	0.012	0.011
Iron	14	13.1	14.8	26.6	19.2	33.5	20.5	14.6
Lead	0.017	0.012	0.016	0.071	0.034	0.156	0.03	0.02
Magnesium	4.64	3.52	5.09	7.22	5.17	8.7	6.18	5.11
Manganese	0.341	0.545	0.438	0.372	0.297	0.387	0.214	0.209
Molybdenum*	2	7	2	2	<1	13	<1	<1
Nickel	0.016	0.02	0.019	0.028	0.027	0.057	0.022	0.021
Selenium*	-	<10	-	-	-	15	-	-
Strontium*	-	10	-	14	-	44	23	-
Tellurium*	-	<20	-	-	-	<20	-	-
Thallium*	-	<20	-	-	-	<20	-	-
Tin*	-	<5	-	-	-	9	-	-
Titanium	-	0.334	-	0.427	-	0.223	0.311	-
Vanadium*	-	26	-	28	-	39	21	-
Zinc	0.045	0.035	0.041	0.057	0.055	0.133	0.048	0.042
Nitrogen:								
- Kjeldahl	0.43	0.14	0.33	1.42	1.06	3	1.31	0.83
Phosphorus-total	0.297	0.352	0.334	0.614	0.46	1.4	0.531	0.406
Residuals: % of organic material	-	<1	-	-	-	10	-	-

Data Collected in 1979

* Units = µg/g dry weight

+ n=2

Data Source: Ministry of Environment and Parks

TABLE 21
WATER QUALITY DATA SUMMARY
ANDERSON CREEK

Constituent	Site 0300063 Anderson Creek				
	Sample Period	No. of Values	Values*		
			Maximum	Minimum	Mean
Alkalinity:total	1972-1977	24	56	18.5	40.3
Arsenic	1975	2	<0.005	<0.005	<0.005
Boron: dissolved	1972	3	<0.2	<0.1	-
Chloride: dissolved	1972-1977	24	6.3	2.8	4.9
Coliforms:total	1973-1977	20	>2400	80	240 +
fecal	1972-1977	20	1600	14	175 +
Colour True	1972-1977	7	60	<5	29.3
Hardness:total	1972-1977	24	58.5	24.2	47.1
Calcium	1972-1977	23	15.5	6	12.4
Magnesium	1972-1977	23	4.8	2.25	4.0
Metals: total					
Chromium	1972-1977	12	0.007	0.005	<0.005^{+}
Copper	1972-1977	19	0.02	<0.001	<0.001^{+}
Iron	1974-1977	16	1.4	<0.1	0.44
Lead	1972-1977	19	<0.003	<0.001	<0.001^{+}
Manganese	1972-1977	18	0.07	<0.02	0.05
Molybdenum	1975	1	<0.0005	-	-
Nickel	1972-1977	18	0.01	<0.01	0.01
Zinc	1972-1977	19	0.011	<0.005	<0.005^{+}
Nitrogen:Ammonia	1973-1974	6	0.11	<0.01	0.032
Unionized Ammonia	1973-1977	17	0.0003	0.00005	0.0002
Nitrate/Nitrite	1976-1977	7	2	1.46	1.68
Nitrate	1972-1976	7	1.98	1.45	1.67
Nitrite	1972-1978	24	0.015	<0.005	0.006
Organic	1973-1976	14	1.1	0.05	0.34
Kjeldahl	1972-1977	13	2.0	0.03	0.42
total	1972	3	3.11	1.19	1.84
Oxygen: dissolved	1972-1977	23	13.5	10.2	11.39
% saturation	1972-1977	23	130.3	89.4	99.7
pH	1972-1977	20	8	7	7.6 +
Phosphorus:ortho-diss.	1976-1977	19	0.049	0.011	0.019
total dissolved	1973-1977	7	0.063	0.012	0.026
total	1972-1977	24	0.112	0.015	0.04
Potassium:Dissolved	1972-1977	19	2.7	1.1	1.36
Silica Reactive	1972	3	19.1	9.3	14.5
Sodium:Dissolved	1972-1977	17	6.1	3.3	5.16
Solids:total	1972-1977	8	132	80	108
Suspended	1974-1977	16	42	1	7
Dissolved	1972-1977	22	116	62	96.5
Specific Conductivity	1972-1977	22	156	68	126
Sulphate	1972-1977	19	14.1	5.2	8.6
Tannin/Lignin	1972	2	0.5	0.5	0.5
Temperature	1972-1977	24	12.3	3.5	8.2
Turbidity	1976-1977	7	11	0.6	3.5

* All values are as mg/L except
(1) Coliforms as MPN/100 mL (2) Colour as colour units (3) pH
(4) Temperature as °C (5) Specific Conductivity as µS/cm
(6) Turbidity as N.T.U. (7) % Saturation as %

+ Median value
Data Source: Ministry of Environment and Parks

TABLE 21 Continued

Constituent	Site 1100017 Anderson Creek				
	Sample Period	No. of Values	Values*		
			Maximum	Minimum	Mean
Alkalinity:total	1977-1979	9	56.9	26.5	49.9
Boron: dissolved	1978-1979	3	<0.1	<0.1	<0.1
Chloride	1978-1979	7	6.9	5.3	6.01
Coliforms:fecal	1979	1	49	-	-
total	1979	1	79	-	-
Colour:True	1977-1979	12	50	<5	15.42
Hardness:total	1977-1979	12	67	43.6	56.1
Calcium	1977-1979	12	17.1	11.2	14.9
Magnesium	1977-1979	12	5.9	3.8	4.6
Metals: total					
Copper	1977-1979	7	0.006	<0.001	0.002
Iron	1977-1979	9	1.2	0.2	0.41
Lead	1978-1979	8	0.005	<0.001	0.002
Zinc	1978-1979	8	0.11	<0.005	0.019
Nitrogen:Ammonia	1977-1979	8	0.113	0.001	0.025
Unionized Ammonia	1977-1979	8	0.0003	0.0001	0.00018
Nitrate/Nitrite	1977-1979	12	3.7	1.74	2.15
Organic	1978-1979	6	1	0.09	0.41
Kjeldahl	1977-1978	12	1	0.1	0.34
total	1977-1979	10	5	2.16	2.64
Oxygen : dissolved	1977-1979	9	17	8.25	11.13
% saturation	1977-1979	9	159.3	76.4	105.2
pH	1977-1979	12	8.1	7.3	7.8 +
Phosphorus:ortho-Diss.	1977-1979	8	0.049	0.014	0.019
total dissolved	1977-1979	8	0.067	0.017	0.024
total	1977-1979	12	0.093	0.022	0.032
Potassium:Dissolved	1978-1979	6	2.7	1.1	1.42
Sodium:Dissolved	1978-1979	7	7.1	5.9	6.23
Solids:total	1978-1979	3	134	104	116.67
Suspended	1977-1979	4	15	1	5.25
dissolved	1979	3	119	102	111
Salinity	1977	2	0	0	0
Specific Conductivity	1977-1979	12	166	131	150.25
Sulphate	1978-1979	6	14.5	7	8.9
Tannin/Lignin	1977	1	0.2	-	-
Temperature	1977-1979	11	14	5.5	11.25
Turbidity	1977-1979	12	6.9	0.8	1.72

* All values are as mg/L except
(1) Coliforms as MPN/100 mL (2) Colour as colour units (3) pH
(4) Temperature as °C (5) Specific Conductivity as µS/cm (6) Turbidity as N.T.U.
(7) % Saturation as %

+ Median value
Data Source: Ministry of Environment and Parks

TABLE 22
WATER QUALITY DATA SUMMARY
MURRAY CREEK

Constituent	Site 0300064 Murray Creek				
	Sample Period	No. of Values	Values*		
			Maximum	Minimum	Mean
Alkalinity:total	1972-1977	24	53.5	17	37.7
Arsenic	1975	2	0.005	<0.005	-
Boron : dissolved	1972	3	<0.2	<0.1	-
Chloride: dissolved	1972-1977	24	8.7	2	4.3
Coliforms:fecal	1973-1979	21	>2400	79	350 +
total	1972-1977	19	3500	110	1300 +
Colour True	1972-1977	7	50	20	33
Hardness:total	1972-1977	24	51	18	37
Calcium	1972-1977	24	12	4.2	8.7
Magnesium	1971-1977	23	5.1	1.8	3.7
Metals: total					
Chromium	1972-1977	11	0.013	<0.005	0.006
Copper	1972-1977	19	0.02	<0.001	0.003
Iron	1974-1977	16	1.6	0.30	0.65
Lead	1972-1977	19	0.005	<0.001	0.002
Manganese	1972-1977	18	0.05	0.01	0.032
Molybdenum	1975	1	0.007	0.007	
Nickel	1972-1977	18	0.01	<0.01	<0.01
Zinc	1972-1977	19	0.009	<0.005	0.006
Nitrogen:Ammonia	1974-1977	16	0.161	0.014	0.055
Unionized Ammonia	1974-1977	14	0.0007	0.000083	0.0003
Nitrate/Nitrite	1972-1977	7	1.84	0.78	1.22
Nitrate	1972-1977	17	4.1	0.36	1.22
Nitrite	1972-1977	24	0.036	<0.005	0.009
Organic	1973-1977	14	1.01	0.15	0.43
Kjeldahl	1972-1977	18	1.117	0.12	0.44
total	1972	3	1.72	0.95	1.42
Oxygen: dissolved	1972-1977	23	13.3	9.9	11.68
% saturation	1972-1977	23	123.5	88.8	102.4
pH	1972-1973	20	8.3	7	7.5 +
Phosphorus:ortho-Diss.	1973-1977	19	0.118	0.015	0.037
total dissolved	1976-1977	7	0.152	0.027	0.059
total	1972-1977	24	0.201	0.026	0.068
Potassium:Dissolved	1972-1977	19	3.8	1.5	2.13
Silica:Reactive	1972	3	16.4	5.7	10.9
Sodium:Dissolved	1972-1977	17	9.1	3.2	6.14
Solids:total	1972-1977	8	110	64	93
Suspended	1974-1977	16	55	2	10
dissolved	1972-1977	22	124	46	85
Specific Conductivity	1972-1977	21	163	56	108
Sulphate	1974-1977	18	12.8	<5	5.8
Tannin/Lignin	1974	2	2.7	0.7	1.7
Temperature	1972-1977	24	14.5	1	8.3
Turbidity	1972-1975	7	12	2.6	7

* All values are as mg/L except
(1) Coliforms as MPN/100 mL (2) Colour as colour units (3) pH
(4) Temperature as °C (5) Specific Conductivity as µS/cm (6) Turbidity as N.T.U.
(7) % Saturation as %

+ Median value
Data Source: Ministry of Environment and Parks

TABLE 22 Continued

1100022 MURRAY CREEK AT 48 AVENUE

Constituent	Period of Record	NO. OF VALUES	VALUES*		
			MAXIMUM	MINIMUM	MEAN
Alkalinity:Total	1974-1979	23	54.5	16.5	41.4
Boron: dissolved	1974-1979	21	<0.1	<0.1	<0.1
Carbon:organic	1974-1979	22	23	<1	6.3
inorganic					
Chloride	1974 1979	30	19	2.3	4.4
Coliform:fecal	1979	1	70	-	-
total	1979	1	220	-	-
Colour (true)	1974-1979	15	150	15	38
Fluoride	1979	5	50	20	28
Hardness:					
Total	1976-1979	19	51.3	22.8	38
Calcium	1974-1979	39	11.8	4	9.0
Magnesium	1979	5	5.3	3.1	4.1
Metals:Total					
Cadmium	1974-1976	15	<0.0005	<0.0005	<0.0005
Copper	1974-1979	11	0.016	<0.001	0.003
Iron	1974-1979	31	8.6	0.3	1.3
Lead	1974-1979	23	0.004	<0.001	0.001
Zinc	1974-1979	23	0.12	<0.005	0.012
Nitrogen:					
Ammonia	1972-1979	14	0.207	0.012	0.067
Un-ionized Ammonia	1976-1979	14	0.0007	0.0001	0.0003
Kjeldahl	1974-1979	40	3	0.11	0.48
Nitrate/nitrite	1974-1979	40	2.53	0.43	1.06
Organic	1978-1979	5	1.0	0.21	0.45
Total	1974-1979	12	3	0.87	1.48
Oxygen:dissolved	1974-1979	30	14.2	6.0	10.4
: % Saturation	1974-1979	30	120.8	62.8	96.6
pH	1974-1979	40	8.0	6.9	7.5^{+}
Phosphorus:					
ortho-diss.	1974-1979	31	0.237	0.015	0.038
total	1974-1979	40	0.572	0.031	0.075
Potassium:Dissolved	1979	3	2	1.7	1.8
Sodium:Dissolved	1979	5	134	105	123.6
Solids:Total	1976-1979	3	106	88	97
Suspended	1976-1979	4	18	3	10
Sulphate	1974-1979	24	6.8	<5	$<5^{+}$
Temperature	1974-1979	35	16.5	3.2	11
Turbidity	1974-1979	40	88	1.1	7.5

* All values are as mg/L except (1) Coliform as MPN/100 mL, (2) Colour as colour units, (3) pH, (4)Temperature as °C, (5) Turbidity as N.T.U. (6) % Saturation as %

Data Source: Ministry of Environment and Parks

TABLE 23

A COMPARISON OF SEDIMENT CONSTITUENTS FROM DIFFERENT LOCATIONS WITHIN B.C.

Constituent	Nicomekl River	Serpentine River	Fraser River[21] (Main Arm)	Sediment Cores From B.C. Lakes[22]	Accumulated Stormwater Sediments - Urban Catchment[24]
Aluminum$^+$	7.58 - 10.9				
Antimony$^+$	0.012 - 0.017				
Arsenic*	<5.0 - 17.0				
Barium$^+$	0.38 - 0.43				
Cadmium$^+$	<0.001	<0.001	0.0065 - 0.007	0.001 - 0.011	<0.001 - 0.019
Calcium$^+$	2.46 - 4.24				
Chromium$^+$	0.021 - 0.36				
Cobalt$^+$	0.014 - 0.022	0.012 - 0.017	0.016 - 0.026	0.010 - 0.063	
Copper$^+$	0.008 - 0.022	0.012 - 0.041	0.018 - 0.026	0.004 - 0.468	0.022 - 0.029
Iron$^+$	14.00 - 26.6	15.2 - 29.0	12.8 - 16.7	2.30 - 121.00	11 - 13.4
Lead$^+$	0.016 - 0.071	0.019 - 0.098	0.004 - 0.008	0.010 - 0.560	0.160 - 0.209
Magnesium$^+$	4.64 - 7.22				
Manganese$^+$	0.209 - 0.438	0.161 - 0.520	0.308 - 0.328	0.016 - 9.96	0.195 - 0.210
Molybdenum*	<1.0 - 2.00				
Nickel$^+$	0.016 - 0.028	0.015 - 0.045	0.035 - 0.050	0.005 - 0.134	
Titanium $^+$	0.311 - 0.427				
Strontium*	14.00 - 23.0				
Vanadium*	21.00 - 28.0				
Zinc$^+$	0.041 - 0.057	0.039 - 0.139	0.028 - 0.047	0.009 - 1.06	0.101 - 0.183

+Unit = mg/g dry weight except as noted by *
*Unit - µg/g dry weight

TABLE 24
WATER QUALITY DATA SUMMARY, BOUNDARY BAY

Constituent	Site 0300070:BOUNDARY BAY WEST				
	Period of Record	No. of Values	Values*		
			Maximum	Minimum	Mean
Alkalinity: total	1980,1982	3	94.8	85.6	89.2
Calcium	1982	1	260	-	-
Chloride	1980,1982	3	13400	11500	12366
Metals:(total)					
cadmium	1982	1	0.001	-	-
copper	1980,1982	2	<0.001	<0.001	<0.001
iron	1980,1982	2	0.017	<0.005	-
lead	1980-1982	2	<0.001	<0.001	<0.001
manganese	1980	1	0.002	-	-
mercury	1980,1982	3	0.00068	<0.00005	<0.00005
nickel	1980,1982	2	<0.01	<0.01	<0.01
zinc	1980,1982	2	0.005	<0.005	-
Nitrogen:					
Ammonia	1982	2	0.03	0.013	0.021
Unionized Ammonia	1974-1980	13	0.0036	0.000092	0.00072
Nitrate	1980,1982	3	0.02	<0.02	<0.02
Nitrite	1980,1982	3	0.006	<0.005	<0.005
Organic	1980,1982	3	0.18	0.05	0.13
Nitrate/Nitrite	1980,1982	3	0.03	<0.02	<0.02
Kjeldahl	1980,1982	3	0.21	0.08	0.16
pH	1980,1982	3	8.3	7.9	8.2 +
Phosphorus: ortho diss	1980,1982	3	0.034	0.006	0.017
total diss.	1980,1982	3	0.038	0.014	0.024
Sulphate:dissolved	1980	1	1562	-	-
Solids: dissolved	1980,1982	2	22900	22200	22550
suspended	1980,1982	2	5	5	5
Specific Conductivity	1980,1982	3	39900	33300	35700
Silica: Dissolved	1982	2	2.1	0.9	1.5
Turbidity	1982	2	1.4	0.5	0.95

* All values are as mg/L except:
(1) pH (2) Specific Conductivity as µS/cm (3) Turbidity as N.T.U.

+ Median value
Data Source: Ministry of Environment and Parks

TABLE 24 Continued

Constituent	Site 0300071:BOUNDARY BAY EAST				
	Period of Record	No. of Values	Values*		
			Maximum	Minimum	Mean
Alkalinity:Total	1980,1982	3	806	85.8	332.3
Chloride	1980,1982	3	16400	10400	12830
Coliform:fecal	1980,1982	2	5	<2	-
Hardness: Calcium	1982	1	240	-	-
Magnesium	1982	1	690	-	-
Metals: (total)					
cadium	1982	1	0.0015	-	-
chromium	1980,1982	3	0.016	0.005	0.009
copper	1980,1982	3	0.002	<0.001	<0.001
iron	1980,1982	3	0.076	0.018	0.048
lead	1980,1982	2	0.001	<0.001	-
mercury	1982	1	<0.00005	-	-
nickel	1980,1982	3	<0.01	<0.01	<0.01
zinc	1980	1	0.01	-	-
Nitrogen:					
Ammonia	1980,1982	3	0.042	<0.01	0.014
Un-ionized Ammonia	1974-1980	13	0.0026	0.0002	0.00096
Nitrate	1980.1982	3	0.17	<0.02	0.06
Nitrite	1980,1982	3	0.079	<0.005	0.03
Organic	1980,1982	3	0.3	0.03	0.2
Nitrate/Nitrite	1980,1982	3	0.18	<0.02	0.06
Oxygen:Dissolved	1980	1	10.4	-	-
pH	1980,1982	3	8.3	8.0	8.0+
Phosphorus: ortho diss	1980,1982	3	0.056	0.005	0.028
total diss.	1980,1982	3	0.065	0.013	0.037
Solids: Suspended	1980,1982	3	9	5	3
Specific Conductivity	1980,1982	3	44900	32100	36400
Sulphate: dissolved	1980	1	1538	-	-
Tannin & Lignin	1982	1	<0.01	-	-
Temperature	1980	1	10.4	-	-
Turbidity	1980,1982	2	2.3	0.7	1.5

* All values are as mg/L except:
(1) Coliform as MPN/100 mL (2) pH (3) Temperature as °C
(4) Turbidity as N.T.U.

+ Median value

Data Source: Ministry of Environment and Parks

TABLE 25

BOUNDARY BAY CRAB FISHERY

YEAR	QUANTITY OF CATCH*	NUMBER OF FISHING DAYS
1980	78 000	922
1981	60 000	1288
1982	30 800	627
1983	47 600	491
1984	54 578	464

* measured in kg

DATA SOURCE: Annual Statistical Summary of the Crab Fishery in Area 29 (Boundary Bay) Department of Fisheries and Oceans, Nanaimo, B.C.

TABLE 26

BOUNDARY BAY HERRING FISHERY

YEAR	NUMBER OF SPAWNS PER YEAR	AVERAGE SPAWN LENGTH *	AVERAGE DAYS OF SPAWN
1979	0	0	0
1980	1	914	59
1981	0	0	0
1982	0	0	0
1983	0	0	0
1984	1	914	59
1985	0	0	0

* MEASURED IN METRES

DATA SOURCE: FEDERAL FISHERIES: Annual Statistical Summary of Herring Spawning Data in Area 29 (Boundary Bay) Department of Fisheries and Oceans, Nanaimo, B. C.

TABLE 27
BACTERIOLOGICAL DATA SUMMARY: BOUNDARY BAY

		JUNE		JULY		AUGUST		90th PERCENTILE
SITE NO*	PERIOD	RANGE	MEDIAN	RANGE	MEDIAN	RANGE	MEDIAN	
1	1982-1985	<3-240	43	7-1100	240	<3-93	15	438
1A	1979-1981	<3-460	23	<3->2400	33	9-1100	43	716
2	1982-1985	4-460	68	9->2400	33	<3-460	4	240
2A	1979-1981	9->2400	33	<3->2400	195	<3-1100	43	1100
3	1982-1985	4-240	43	9-460	93	4-240	23	240
3A	1979-1981	4-1100	33	<3-1100	98	<3-240	23	972
4	1982-1985	<3-1100	23	21->2400	122	<3->2400	7	1880
4A	1979-1981	15-240	43	<3-1100	43	4->2400	10	460
5	1982-1985	4-93	23	7-460	33	7-93	23	93
5A	1979-1981	<3-460	43	<3-460	15	<3-240	23	240
6	1982-1985	<3-1100	43	15-240	23	<3-75	15	240
6A	1979-1981	<3->2400	23	4-240	23	<3-1100	26	350
7	1982-1985	<3-43	9	4-1100	43	7-240	7	43
7A	1979-1981	4-43	9	<3-1100	9	3-1100	11	82
8	1982-1985	<3-150	6	<3-460	15	4-1100	33	360
8A	1979-1982	<3-23	6	4-460	43	4-23	9	212
9	1982-1985	<3-1100	23	4-150	18	9-43	18	177
9A	1979-1981	<3-240	23	<3-460	9	<3-43	23	240
10	1982-1979	<3->2400	23	7->2400	93	4->2400	93	>2400
10A	1979-1981	<3-460	13	<3->2400	23	<3-93	15	460
11	1982-1985	4-150	7	9-93	23	<3-93	4	93
11A	1979-1981	7-93	23	<3-1100	43	4->2400	23	972

* Sites identified by "A" are in close proximity to those with the same number identifier.

Data Source: Ministry of Health; Boundary Health Unit

TABLE 28

ESTIMATED NUTRIENT LOADINGS FROM DIFFUSE AGRICULTURAL SOURCES

NITROGEN VALUES kg/year

DISCHARGE TO	FINISHING CATTLE	COWS	CALVES	YEARLINGS	TOTAL
Sam Hill Cr.	3 400			11 970	15 370
Little Campbell R.	9 044	1 972	49		11 064
Nicomekl R.	5 100	5 304	141	160	10 704
Serpentine R.	345 100	5 644	163	42 972	393 879

PHOSPHORUS VALUES kg/year (P)

DISCHARGE TO	FINISHING CATTLE	COWS	CALVES	YEARLINGS	TOTAL
Sam Hill Cr.	235			966	1 201
Little Campell R.	625	230	6		861
Nicomekl R.	352	618	17	13	1 000
Serpentine R.	23 842	657	20	3 471	28 001

TABLE 29

MAXIMUM CONCENTRATION OF TOTAL AMMONIA NITROGEN FOR PROTECTION OF AQUATIC LIFE
(mg/L-N)

pH	Temp. 0.0	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0
6.5	27.7	28.3	27.9	27.5	27.2	26.8	26.5	26.2	26.0	25.7	25.5
6.6	27.9	27.5	27.2	26.8	26.4	26.1	25.8	25.5	25.2	25.0	24.7
6.7	26.9	26.5	26.2	25.9	25.5	25.2	24.9	24.6	24.4	24.1	23.9
6.8	25.8	25.5	25.1	24.8	24.5	24.2	23.9	23.6	23.4	23.1	22.9
6.9	24.6	24.2	23.9	23.6	23.3	23.0	22.7	22.5	22.2	22.0	21.8
7.0	23.2	22.8	22.5	22.2	21.9	21.6	21.4	21.1	20.9	20.7	20.5
7.1	21.6	21.3	20.9	20.7	20.4	20.2	19.9	19.7	19.5	19.3	19.1
7.2	19.9	19.6	19.3	19.0	18.8	18.6	18.3	18.1	17.9	17.8	17.6
7.3	18.1	17.8	17.5	17.3	17.1	16.9	16.7	16.5	16.3	16.2	16.0
7.4	16.2	16.0	15.7	15.5	15.3	15.2	15.0	14.8	14.7	14.5	14.4
7.5	14.4	14.1	14.0	13.8	13.6	13.4	13.3	13.1	13.0	12.9	12.7
7.6	12.6	12.4	12.2	12.0	11.9	11.7	11.6	11.5	11.4	11.3	11.2
7.7	10.8	10.7	10.5	10.4	10.3	10.1	10.0	9.92	9.83	9.73	9.65
7.8	9.26	9.12	8.98	8.88	8.77	8.67	8.57	8.48	8.40	8.32	8.25
7.9	7.82	7.71	7.60	7.51	7.42	7.33	7.25	7.17	7.10	7.04	6.98
8.0	6.55	6.46	6.37	6.29	6.22	6.14	6.08	6.02	5.96	5.91	5.86
8.1	5.21	5.14	5.07	5.01	4.95	4.90	4.84	4.80	4.75	4.71	4.67
8.2	4.15	4.09	4.04	3.99	3.95	3.90	3.86	3.83	3.80	3.76	3.74
8.3	3.31	3.27	3.22	3.19	3.15	3.12	3.09	3.06	3.03	3.01	2.99
8.4	2.64	2.61	2.57	2.54	2.52	2.49	2.47	2.45	2.43	2.41	2.40
8.5	2.11	2.08	2.06	2.03	2.01	1.99	1.98	1.96	1.95	1.94	1.93
8.6	1.69	1.67	1.65	1.63	1.61	1.60	1.59	1.58	1.57	1.56	1.55
8.7	1.35	1.33	1.32	1.31	1.30	1.29	1.28	1.27	1.26	1.26	1.25
8.8	1.08	1.07	1.06	1.05	1.04	1.04	1.03	1.03	1.02	1.02	1.02
8.9	0.871	0.863	0.856	0.849	0.844	0.839	0.836	0.833	0.832	0.831	0.831
9.0	0.703	0.697	0.692	0.688	0.685	0.682	0.681	0.681	0.680	0.681	0.682

	11.0	12.0	13.0	14.0	15.0	16.0	17.0	18.0	19.0	20.0
6.5	25.2	25.0	24.8	24.6	24.5	24.3	24.2	24.0	23.9	23.8
6.6	24.5	24.3	24.1	23.9	23.8	24.6	23.5	23.3	23.3	23.2
6.7	23.7	23.5	23.3	23.1	23.0	22.8	22.7	22.6	22.5	22.4
6.8	22.7	22.5	22.3	22.2	22.0	21.9	21.8	21.7	21.6	21.5
6.9	21.6	21.4	21.3	21.1	21.0	20.8	20.7	20.6	20.5	20.4
7.0	20.3	20.2	20.0	19.9	19.7	19.6	19.5	19.4	19.3	19.2
7.1	18.9	18.8	18.7	18.5	18.4	18.3	18.2	18.1	18.0	17.9
7.2	17.4	17.3	17.2	17.1	16.9	16.8	16.8	16.7	16.6	16.5
7.3	15.9	15.7	15.6	15.5	15.4	15.3	15.2	15.2	15.1	15.1
7.4	14.2	14.1	14.0	13.9	13.9	13.8	13.7	13.6	13.6	13.5
7.5	12.6	12.5	12.4	12.4	12.3	12.2	12.2	12.1	12.1	12.0
7.6	11.1	11.0	10.9	10.8	10.8	10.7	10.7	10.6	10.6	10.5
7.7	9.57	9.50	9.43	9.37	9.31	9.26	9.22	9.81	9.15	9.12
7.8	8.18	8.12	8.07	8.02	7.97	7.93	7.90	7.87	7.84	7.82
7.9	6.92	6.88	6.83	6.79	6.75	6.72	6.69	6.67	6.65	6.64
8.0	5.81	5.78	5.74	5.71	5.68	5.66	5.64	5.62	5.61	5.60
8.1	4.64	4.61	4.59	4.56	4.54	4.53	4.51	4.50	4.49	4.49
8.2	3.71	3.69	3.67	3.65	3.64	3.63	3.62	3.61	3.61	3.61
8.3	2.97	2.96	2.94	2.93	2.92	2.92	2.91	2.91	2.91	2.91
8.4	2.38	2.37	2.36	2.36	2.35	2.35	2.35	2.35	2.35	2.36
8.5	1.92	1.91	1.91	1.90	1.90	1.90	1.90	1.90	1.91	1.92
8.6	1.55	1.54	1.54	1.54	1.54	1.54	1.55	1.55	1.56	1.57
8.7	1.25	1.25	1.25	1.25	1.25	1.26	1.26	1.27	1.28	1.29
8.8	1.02	1.02	1.02	1.02	1.03	1.03	1.04	1.05	1.06	1.07
8.9	0.832	0.834	0.838	0.842	0.847	0.853	0.861	0.870	0.880	0.891
9.0	0.684	0.688	0.692	0.698	0.704	0.711	0.720	0.729	0.740	0.752

TABLE 30

AVERAGE 30-DAY CONCENTRATION OF TOTAL AMMONIA NITROGEN FOR PROTECTION OF AQUATIC LIFE (mg/L-N)

pH	Temp. 0.0	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0
6.5	2.08	2.05	2.02	1.99	1.97	1.94	1.92	1.90	1.88	1.86	1.84
6.6	2.08	2.05	2.02	1.99	1.97	1.94	1.92	1.90	1.88	1.86	1.84
6.7	2.08	2.05	2.02	1.99	1.97	1.94	1.92	1.90	1.88	1.86	1.84
6.8	2.08	2.05	2.02	1.99	1.96	1.94	1.92	1.90	1.88	1.86	1.84
6.9	2.08	2.05	2.02	1.99	1.97	1.94	1.92	1.90	1.88	1.86	1.84
7.0	2.08	2.05	2.02	1.99	1.97	1.94	1.92	1.90	1.88	1.86	1.84
7.1	2.08	2.05	2.02	1.99	1.97	1.94	1.92	1.90	1.88	1.86	1.84
7.2	2.08	2.05	2.02	1.99	1.96	1.95	1.92	1.90	1.88	1.86	1.85
7.3	2.08	2.05	2.02	1.99	1.97	1.95	1.92	1.90	1.88	1.86	1.85
7.4	2.08	2.05	2.02	2.00	1.97	1.95	1.92	1.90	1.88	1.87	1.85
7.5	2.08	2.05	2.02	2.00	1.97	1.95	1.93	1.91	1.88	1.87	1.85
7.6	2.09	2.05	2.03	2.00	1.97	1.95	1.93	1.91	1.89	1.87	1.85
7.7	2.09	2.05	2.03	2.00	1.98	1.95	1.93	1.91	1.89	1.87	1.86
7.8	1.78	1.75	1.73	1.71	1.69	1.67	1.65	1.63	1.62	1.60	1.59
7.9	1.50	1.48	1.46	1.44	1.43	1.41	1.39	1.38	1.36	1.35	1.34
8.0	1.26	1.24	1.23	1.21	1.20	1.18	1.17	1.16	1.15	1.14	1.13
8.1	1.00	0.989	0.976	0.963	0.952	0.942	0.932	0.922	0.914	0.906	0.899
8.2	0.799	0.788	0.777	0.768	0.759	0.751	0.743	0.736	0.730	0.724	0.718
8.3	0.636	0.628	0.620	0.613	0.606	0.599	0.594	0.588	0.583	0.579	0.575
8.4	0.508	0.501	0.495	0.489	0.484	0.479	0.475	0.471	0.467	0.464	0.461
8.5	0.405	0.400	0.396	0.381	0.387	0.384	0.380	0.377	0.375	0.372	0.370
8.6	0.324	0.320	0.317	0.313	0.310	0.308	0.305	0.303	0.301	0.300	0.298
8.7	0.260	0.257	0.254	0.251	0.249	0.247	0.246	0.244	0.243	0.242	0.241
8.8	0.208	0.206	0.204	0.202	0.201	0.200	0.198	0.197	0.197	0.196	0.196
8.9	0.168	0.166	0.165	0.163	0.162	0.161	0.161	0.160	0.160	0.160	0.160
9.0	0.135	0.134	0.133	0.132	0.132	0.131	0.131	0.131	0.131	0.131	0.131

pH	11.0	12.0	13.0	14.0	15.0	16.0	17.0	18.0	19.0	20.0
6.5	1.82	1.81	1.80	1.78	1.77	1.64	1.52	1.41	1.31	1.22
6.6	1.82	1.81	1.80	1.78	1.77	1.64	1.52	1.41	1.31	1.22
6.7	1.83	1.81	1.80	1.78	1.77	1.64	1.52	1.41	1.31	1.22
6.8	1.83	1.81	1.80	1.78	1.77	1.64	1.52	1.42	1.32	1.22
6.9	1.82	1.81	1.80	1.78	1.77	1.64	1.53	1.42	1.32	1.22
7.0	1.83	1.81	1.80	1.79	1.77	1.64	1.53	1.42	1.32	1.22
7.1	1.83	1.81	1.80	1.79	1.77	1.65	1.53	1.42	1.32	1.23
7.2	1.83	1.81	1.80	1.79	1.78	1.65	1.53	1.42	1.32	1.23
7.3	1.83	1.82	1.80	1.79	1.78	1.65	1.53	1.42	1.32	1.23
7.4	1.83	1.82	1.80	1.79	1.78	1.65	1.53	1.42	1.32	1.23
7.5	1.83	1.82	1.81	1.80	1.78	1.66	1.54	1.43	1.33	1.23
7.6	1.84	1.82	1.81	1.80	1.79	1.66	1.54	1.43	1.33	1.24
7.7	1.84	1.83	1.81	1.80	1.79	1.66	1.54	1.44	1.34	1.24
7.8	1.57	1.56	1.55	1.54	1.53	1.42	1.32	1.23	1.14	1.07
7.9	1.33	1.32	1.31	1.31	1.30	1.21	1.12	1.04	0.970	0.904
8.0	1.12	1.11	1.10	1.10	1.09	1.02	0.944	0.878	0.818	0.762
8.1	0.893	0.887	0.882	0.878	0.874	0.812	0.756	0.704	0.655	0.611
8.2	0.714	0.709	0.706	0.703	0.700	0.651	0.606	0.565	0.527	0.491
8.3	0.571	0.568	0.566	0.564	0.562	0.523	0.487	0.455	0.424	0.396
8.4	0.458	0.456	0.455	0.453	0.452	0.421	0.393	0.367	0.343	0.321
8.5	0.369	0.367	0.366	0.366	0.365	0.341	0.318	0.298	0.278	0.261
8.6	0.297	0.297	0.296	0.296	0.296	0.277	0.259	0.242	0.227	0.213
8.7	0.241	0.240	0.240	0.241	0.241	0.226	0.212	0.198	0.186	0.175
8.8	0.196	0.196	0.196	0.197	0.198	0.185	0.174	0.164	0.154	0.145
8.9	0.160	0.161	0.161	0.162	0.163	0.153	0.144	0.136	0.128	0.121
9.0	0.132	0.132	0.133	0.134	0.135	0.128	0.121	0.114	0.108	0.102

- the average of the measured values must be less than the average of the corresponding individual values in Table 30.
- each measured value is compared to the corresponding individual values in Table 30.